THE UNIVERSITY OF ALBERTA

SUPPLY, DEMAND AND PRICE RELATIONSHIPS BETWEEN NATURAL GAS AND SOME DERIVED PETROCHEMICALS

by

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ABSTRACT

A model was developed to predict the effects of natural gas supply and demand on both the prices of natural gas and the prices of chemicals manufactured from natural gas. The model consisted of three parts. The first section determined the markets for various Alberta-produced chemicals and the sensitivity of the markets to such factors as natural gas price, tariffs, freight rates, and plant size. This case constituted full natural gas supply. In the second part of the analysis, the effect of natural gas shortage on chemical and natural gas prices was investigated. The last section of the model approximated natural gas prices from the demand for various chemicals. In this analysis, commodity price was dictated by the price consumers are willing to pay, regardless of the costs of producing that commodity. The difference between production costs and demand price determined the natural gas price that chemical producers could afford. It was this gas price which was calculated.

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CHAPTER I

INTRODUCTION

It has been widely accepted that natural gas demand is outstripping conventional supply in the United States (1, 2). Consequently, unless major new gas discoveries are made, serious natural gas shortages will occur by the late 1970's. It is the object of this study to determine the effects of natural gas shortfalls on the chemical industry, which is a principal industrial consumer of natural gas.

One consequence of the uncertainty of natural gas supply in the United States is that attention has focused on Alberta as a source of relatively secure gas supplies.

Natural gas is an important chemical feedstock. Alberta is therefore becoming the site of a major chemical industry.

Several proposals have been presented to construct large chemical plants in this province (3), but market studies must be carried out to ascertain the number and size of plants which should be built. In Chapters II through V, the markets for ammonia, methanol, and ethylene, the three major proposed chemicals, and the sensitivity of the markets to such factors as natural gas price, tariffs, and freight rates are determined.

Natural gas shortages have two other far-reaching effects: higher natural gas prices, and periodic shutdowns of industry. The first effect is obvious from fundamental economics. If demand of a commodity exceeds potential supply at a given price, market forces cause

the price to increase. Determining a demand curve for natural gas is therefore important in estimating natural gas prices. In Chapter VIII, a natural gas demand curve is derived from an ammonia demand curve, ammonia being manufactured from natural gas.

Periodic industry shutdowns, of course, are already occurring in the United States. Electrical "brownouts" are common along the East Coast. These industry shutdowns have resulted in shortages of commodities produced by these industries. The Arab oil embargo caused widespread gasoline rationing in the U.S. in 1974. Similarly, natural gas shortages will cause shortfalls in various chemical industries. The question is: what determines who will receive gas supplies?

In the United States, the Federal Power Commission controls the supply and price of domestic gas (4). This government body has two alternatives to dealing with the problem of natural gas supply: either it can regulate the industry and gas supplies would be rationed, or it can deregulate the natural gas industry and allow gas prices to seek their competitive market level. These two alternatives are examined with respect to the ammonia and methanol industries, the two largest chemical natural gas consumers.

CHAPTER II

MARKET STUDY MODEL

In any market model, price is one of the most important inputs into the system. The market model described in this chapter, for example, is based on geographical prices, specifically the prices of petrochemicals in various areas of North America.

Of course, several pricing systems are contained within the boundaries of geographical prices. When a seller quotes an f.o.b. plant gate price, it implies that the buyer pays transportation charges from the plant to the retail outlet. In this study, f.o.b. prices are defined as loaded in the transport medium (rail, pipeline or water) at the plant gate, and include a 20% investment return to the producer.

Sometimes producers quote a "zone price" (5), in which case an area is divided into zones and the same transportation charge is levied to each market in the zone, regardless of actual transportation charges to the market.

A delivered price quote infers that prices to all areas are identical, with the seller paying for transportation. The return to the seller varies with the distance from plant to market.

Another pricing system is basing - point pricing (5), where prices are quoted for certain base points. A buyer pays for the transportation from the nearest basing point, regardless of actual shipment origin. This system allows for a standardization of transportation charges.

There are thus many pricing systems available. The choice of an f.o.b. plant price and modifications of this price was simply made because of the ease of application.

The model used in the market penetration study for Alberta-produced chemicals was based on a simple cost analysis. The cost of these chemicals in a market area would equal the production costs, plus transportation charges, plus any tariffs and taxes levied on these goods. The price of Alberta product in the market area was compared to Gulf Coast costs, since the majority of the U.S. chemical industry is located there, and also because the Gulf Coast has been the price leader for over twenty years. The fundamental assumption used was that potential consumers would buy the product from the cheapest supplier.

The parameters which comprise the manufacturing costs for a given plant size are shown in Table 1. Alberta and Gulf Coast utility costs (6), which are constant for each commodity studied, are also shown. For this analysis, a breakeven operating cost comparison was used. This cost was assumed to equal f.o.b. price minus profit and depreciation. The difference between the market price and the breakeven price is simply the producer's profit and capital recovery. If the Alberta producer cannot meet the Gulf Coast breakeven price in a market area, then he will not sell his product there; if an f.o.b. price analysis was used, producers could simply reduce their profit margins in order to capture the market.

The cost of a commodity in the market area is best illustrated in Table 2. If rail freight rates of 2¢/Ton-mile are assumed (7), the cost of a chemical within a 100-mile radius of a plant site would equal the breakeven manufacturing cost plus 1¢.lb freight charges.

Table 1

Chemical Manufacturing Costs

		ALBERTA	COMMON	GULF COAST
*FIXED CAPITAL	$MM	X		Y
WORKING CAPITAL	$MM	X		Y
TOTAL	$MM	X		Y
NATURAL GAS			X	
FUEL			X	
CHEMICALS			X	
ELECTRICITY			$.01/KWH	
PROCESS WATER			$.03/MGAL	
COOLING WATER			$.035/MGAL	
STEAM		$1.00/MLB		$1.20/MLB
LABOR			$6.50/HR	
MAINTENANCE			X% OF FIXED CAPITAL	
OVERHEAD			120% OF LABOR	
TAXES			1.5% OF FIXED CAPITAL	
SALES, ADMINISTRATION			X% OF TOTAL SALES	
DEPRECIATION			10% OF FIXED CAPITAL	
PROFIT			20% OF TOTAL CAPITAL	
PLANT GATE PRICE		X¢/lb		Y¢/lb

*Capital costs are greater in Alberta due to:

1. Winter construction
2. Cost of transporting major equipment
3. Federal tax on construction materials

Imported chemicals into the U.S. would include a tariff, which, in the case of methanol, would be 1.1¢/lb (8). Similarly, Gulf Coast methanol sold in Montreal would include a 10% tariff (.2-.3¢/lb) (9). It should be noted that these numbers were used as initial estimates to illustrate the method.

Table 2

Chemical Costs in a Market Area

DISTANCE FROM PLANT LOCATION	ALBERTA	GULF COAST
PLANT GATE PRICE = PRODUCTION COSTS	1.0¢/lb	0.9¢/lb
COST @ 500 MILES	1.0 + 0.5 = 1.5 (FREIGHT)	0.9 + 0.5 = 1.4
COST @ 500 MILES (EXPORTED)	1.5 + 1.1 = 2.6 (TARIFF)	1.4 + 0.2 = 1.6

From such a table of chemical cost as a function of distance from a plant location, iso-cost lines emanating from Alberta (Medicine Hat) and the Gulf Coast (Beaumont) were drawn on a map of North America, as shown in Figure 1. Each line is an equal-cost line designating 500 miles by rail, and represents the production cost, plus tariff, plus transportation charges at that boundary. A discontinuity in the iso-cost lines arises along the 49th parallel because of the tariff on imports. Also, significant quantities of chemicals are shipped by tanker from the Gulf Coast to San Francisco and New York and via barge up the Mississippi River to Chicago. Because water transport is much cheaper than by rail, these locations were also used as focal points on the map. Hence, if Alberta methanol was produced for 1¢/lb, it would cost 3.8¢/lb in San Francisco, including 1.1¢/lb tariff and 1.7¢/lb rail freight rates. If a barge-tanker rate of

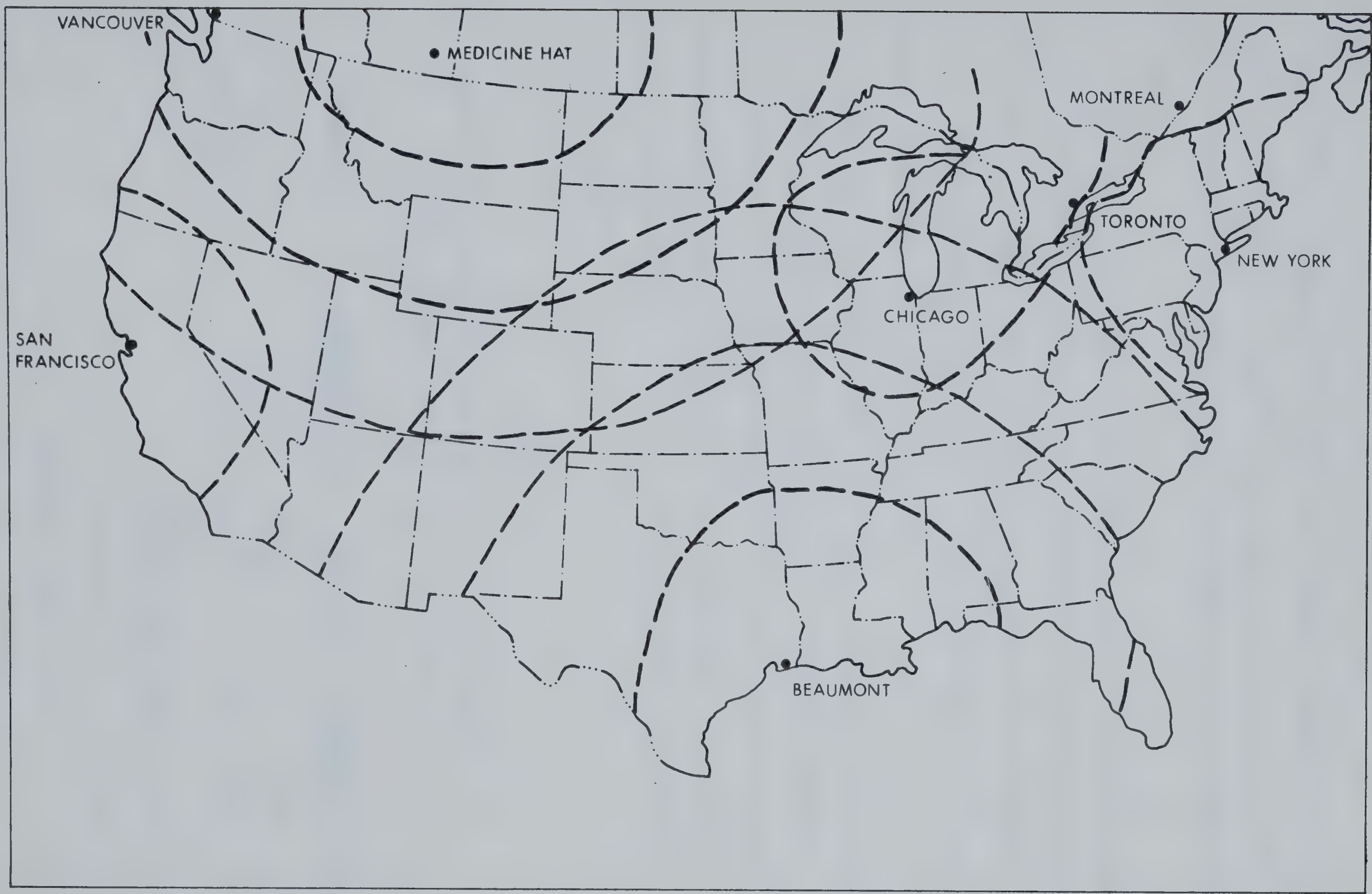

Figure 1. Iso-cost Lines

.5¢/Ton-mile was assumed(10), Gulf Coast methanol produced for 1¢/lb would be shipped to San Francisco for only 1.1¢/lb, and sold there for 2.1¢/lb. Alberta methanol would therefore not be marketed in this area.

From the intersection of the iso-cost lines, a line representing equal cost of Alberta and Gulf Coast chemicals was obtained, as shown in Figure 2. This line would designate the respective Alberta and Gulf Coast markets. Alberta product would be marketed in all areas west and north of this line.

The location of this line is influenced by several main factors: the price of feedstock, plant capacity, tariffs levied on imports, freight rates, and feedstock availability. The sensitivity of the market to variations in these factors was examined. Natural gas prices have the greatest effect on first-generation chemicals, as shown in Table 3:

Table 3

Gas Cost as a Fraction of Commodity Plant Gate Prices
Basis: 25¢/MCF Natural Gas, Large Plants

COMMODITY	GAS COST / COMMODITY PRICE	COMMODITY	GAS COST / COMMODITY PRICE
Methanol	0.250	Ammonia	0.191
Formaldehyde	0.078	Urea	0.070
		Urea-Formaldehyde resin	0.073
		Plywood	0.008

Sources: (10, 11, 12)

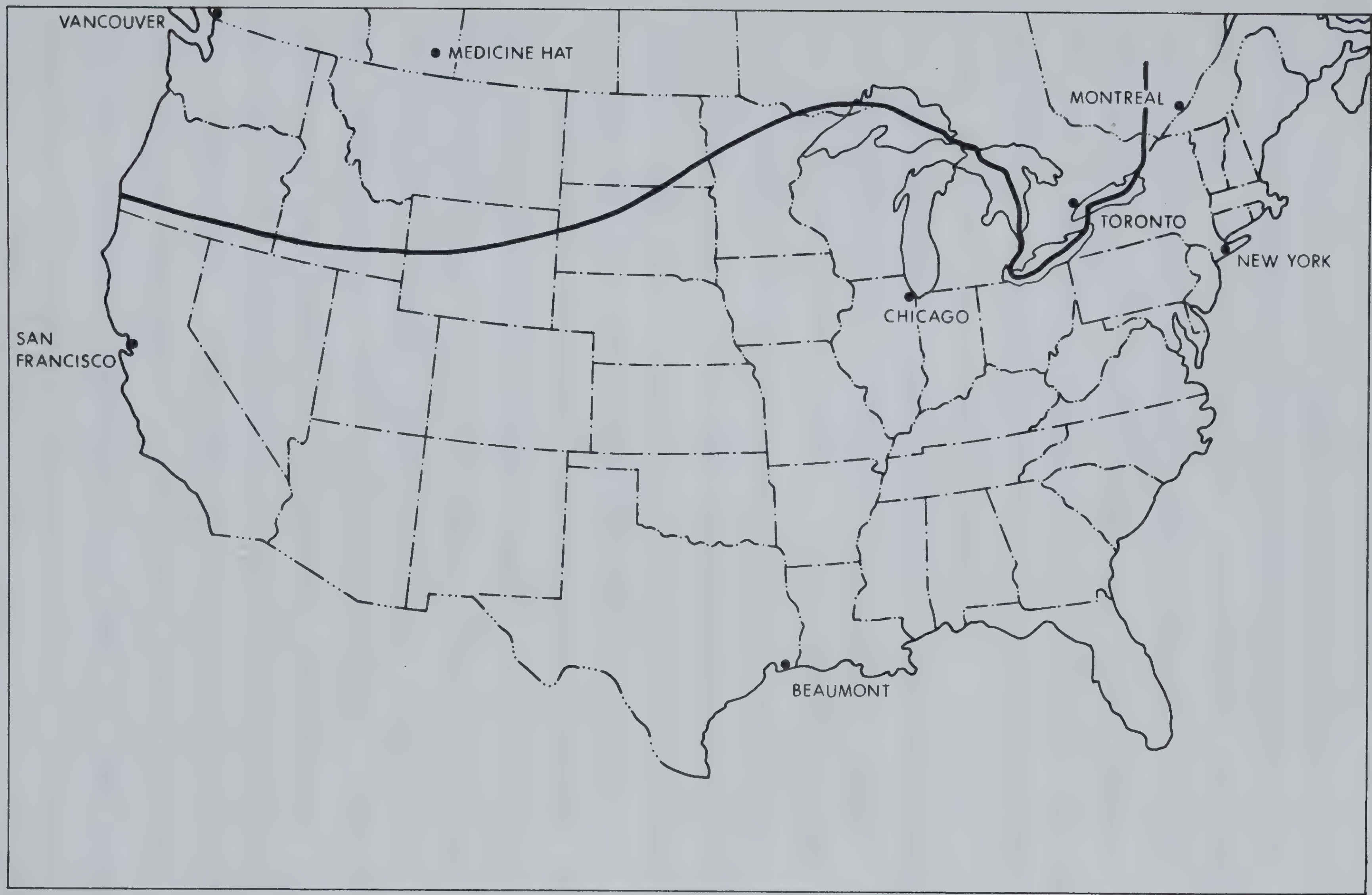

Figure 2. Hypothetical Market Line

As the chemical is further processed, the feedstock cost as a fraction of chemical cost reduced. Natural gas forms 25% of methanol plant gate costs, but when the methanol is converted to the resin used in plywood, the natural gas component reduces to about 7%. For this reason, primary chemicals such as ammonia, methanol, and ethylene were used in the market penetration study. The market for these commodities was also examined because they will be manufactured by the proposed chemical complexes shown in Table 4.

The method used in determining the market sensitivity to natural gas prices and feedstock supply will now be discussed. Because natural gas prices in Alberta and the U.S. are government-controlled, it is difficult to predict what future gas prices will be. Therefore, Alberta and Gulf Coast production costs were calculated using nominal gas prices, but it was the difference between these natural gas prices which was used in determining market sensitivities.

The question of natural gas supply must also be considered, since U.S. demand is outstripping productive capacity. As a result, gas shortages will become increasingly frequent. Plants will shut down for periods when feedstocks are not available. If a plant is shut down, manufacturing costs will rise because charges such as labor are constant, but less chemical will be produced. For example, the labor cost of a 400 MM lb/yr methanol plant operating at capacity is about 0.06¢/lb (13). If this plant was to shut down for 20% of the year, the labor charge would be 120% of .06¢ or .072¢/lb. However, feedstock contribution to manufacturing costs would not change because feedstock use is proportional to the plant production. This method of analysis was used to determine the effect of down time on chemical

Table 4

Proposed Alberta Chemical Plants

COMPANY	CHEMICAL		PLANT SIZE
ALBERTA AMMONIA	AMMONIA		5000 TON/DAY
ALBERTA GAS CHEMICALS	*METHANOL		600 TON/DAY
	*METHANOL		600 TON/DAY
	METHANOL		1200 TON/DAY
	AMMONIA		1150 TON/DAY
	UREA		1960 TON/DAY
ALBERTA GAS ETHYLENE	*ETHYLENE		1.2 BILLION/YR
CALGARY PETROCHEMICAL DEVELOPMENTS	AMMONIA		400 TON/YR
CANADIAN FERTILIZERS	*AMMONIA		1200 TON/YR
	*UREA		1500 TON/DAY
	AMMONIA		2 - 1200 TPD UNITS
	UREA		1500 TPD
CIL	POLYETHYLENE		400 MM LB/YR
	*AMMONIUM NITRATE		250 MTON/YR
COMINCO	*AMMONIA		400 MTON/YR
	*UREA		480 MTON/YR
DOW	*STYROFOAM		----
PANCANADIAN PETROLEUM	AMMONIA		400 MTON/YR
SHERRITT GORDON MINES	*AMMONIA EXPANSION	TO	1500 TON/DAY
	*UREA EXPANSION	TO	1200 TON/DAY

*Indicates definite construction (3)

All other plants indefinite

markets.

Two points must be made about the market analysis. One is that the method used is applicable only in a commodity oversupply situation, ie. where productive capacity exceeds demand. In this instance, markets are determined by price of commodities in the market area. When demand exceeds capacity, a commodity shortage exists, and prices are no longer determined by the costs of production. Producers can sell their goods at whatever price the market will bear.

The other point which should be noted is that at the market line, because breakeven production costs were used in determining its location, producers make no profit and recover no capital. However, when he markets his product 100-miles inside the market line, he would make the equivalent of his competitor's transportation charges plus any tariffs levied over the 100-mile distance. The price of a commodity would therefore be maximum at the plant gate.

CHAPTER III

METHANOL MARKET ANALYSIS

Before examining the market for Alberta-produced methanol, it might be informative to review the history of methanol production in Alberta. In the early 1950's Canadian Chemical Ltd.(now Celanese Canada) constructed a complex in Edmonton to produce a variety of petrochemicals from hydrocarbon feedstocks (14). One of the byproducts of the operation was 15 million pounds per year of chemical grade methanol which was used captively in formaldehyde production. This plant was a reasonable size for a methanol plant at that time. However, when large methanol plants such as the 1300 MM pound per year plant at Beaumont, Texas was built in the U.S. (11), methanol produced at the Chemcell plant became more expensive than that imported from the Gulf Coast. A combination of the economies of scale of large plants and the tariff structure arranged during the Kennedy Round made methanol produced in Edmonton non-competitive with Gulf Coast product. Consequently, Celanese shut down its Edmonton methanol plant and began importing from the Gulf Coast. The situation across Canada was much the same with Canadian methanol being more expensive in Canadian markets than U.S. methanol.

This situation now appears to be undergoing significant change. As shortages of natural gas feedstocks developed along the Gulf Coast, the cost of producing petrochemicals increased dramatically. As a result attention has focused on Alberta as a source of secure natural gas supplies at unspecified prices. These factors have encouraged a

number of major chemical companies to make proposals to the Provincial Government for the construction of methanol plants in Alberta which would use natural gas feed. This study will investigate the market for methanol produced in Alberta and the sensitivity of this market to changes in natural gas price and supply, plant size, tariffs, and freight rates. The analytical framework for the study was discussed in Chapter II and will now be applied directly to the methanol industry. It should be noted that contractual arrangements are carried out between buyer and seller on an individual basis, therefore this analysis points to trends in market potential and not exact markets themselves.

The major use of methanol is for the production of formaldehyde which is then used primarily for producing urea-formaldehyde resins for bonding of wood materials such as plywood (10,11). Because of this fact, formaldehyde capacity is important in analyzing the methanol market. Since most of the marketable U.S. forest reserves are in the Pacific Northwest and southeastern U.S., this is where the majority of the U.S. formaldehyde industry is located, as shown in Figure 3. Methanol consumption for formaldehyde production in each area is designated on the figure in millions of pounds per year (15, 16). Methanol, although used mostly for formaldehyde, is also used in the synthesis of organic solutions, but these plants are located almost exclusively along the Gulf Coast and in New Jersey. The areas shown thus represent the major market areas for methanol in North America. New market locations will undoubtedly be influenced by a variety of factors, one of the primary ones being availability and price of methanol at the plant sites.

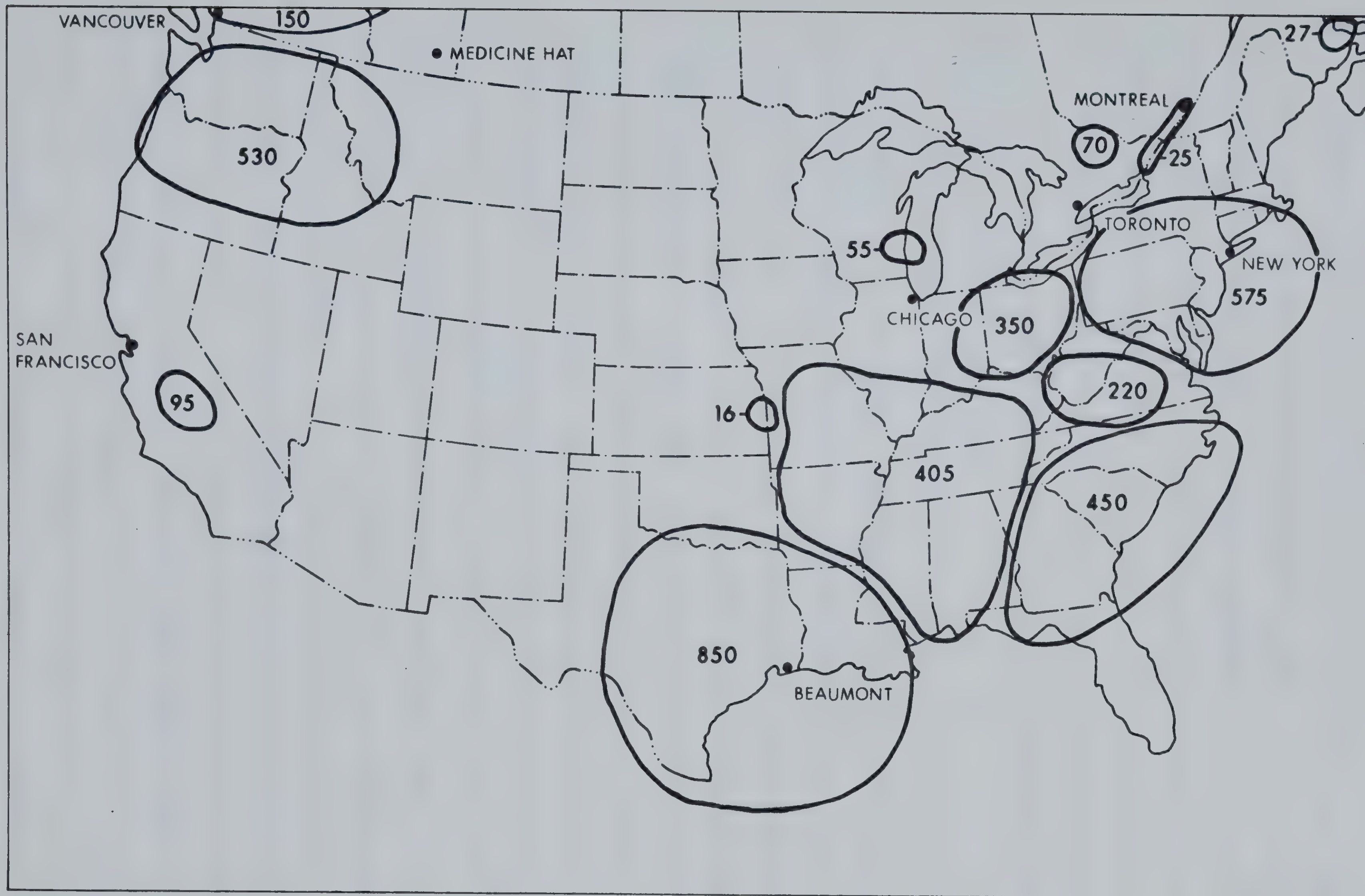

Figure 3. Methanol Consumed for Formaldehyde (MM lb.)

Since this study deals primarily with changes in the market area as a result of changes in the aforementioned variables, it is necessary to establish a base case. A comparison between a 400 million pound per year plant located in southern Alberta and a 1300 million pound per year Gulf Coast plant will be used as the reference case. The Alberta plant is typical of the size of one of the proposed plants and the U.S. plant is approximately equal in size to the Dupont plant producing at Beaumont, Texas (15).

Production costs for the Alberta and Gulf Coast plants (6) are shown in Table 5. Using 25¢/Mcf natural gas feed, an Alberta plant could produce methanol for 2.4¢/lb on a 20% return basis, and for a breakeven operating cost of 0.9¢/lb. Breakeven price was assumed to equal the total production cost minus the 20% return and depreciation. Using natural gas at the same cost, a Gulf Coast manufacturer could produce methanol for about 1.5¢/lb including profit, and 0.7¢/lb on a breakeven basis, as shown. Using this gas price was arbitrary but it had some basis in that this price was typical of long-term natural gas contracts that existed in Alberta and the Gulf Coast until the early 1970's. It should be pointed out that the market remains unchanged even if the gas prices are $1.00/Mcf. It is the differential that determines the market. The cost of methanol delivered to the consumer was assumed to equal the production costs plus transportation charges plus any tariffs levied. Obviously this method of determining price is idealistic. In times of oversupply, the producer could reduce his profit margin to capture the market and in periods of undersupply the price and market are dictated more by demand than cost.

For purposes of price determination, transportation charges of

Table 5

Methanol Production Costs

		ALBERTA	GULF COAST
CAPACITY MM LB/YR		400	1300
FIXED CAPITAL $MM		18.9	30.8
WORKING CAPITAL $MM		1.3	3.2
		¢/LB	¢/LB
NATURAL GAS @	$.25/MCF	.255	.255
CATALYST		.065	.065
FUEL @	$.25/MCF	.154	.154
ELECTRICITY		.028	.028
BOILER FEED WATER		.003	.003
LABOR		.064	.019
MAINTENANCE	3.5% FIXED	.165	.082
OVERHEAD		.077	.023
TAXES		.071	.035
DEPRECIATION		.473	.230
SALES	2.0% SALES	.048	.028
PROFIT		1.010	.525
	PLANT GATE COST	2.42	1.45
	BREAKEVEN COST	.93¢/lb	.69¢/lb

2¢/Ton-mile by rail and .5¢/Ton-mile by large scale water transport such as barge were assumed. Since railroads parallel major roads(5), rail rates were based upon road distances and water transport distances were measured on a map. The tariffs levied on methanol, which were established by the Kennedy Round, are 1.1¢/lb on methanol imported to the U.S. and 0.2¢/lb on Canadian imports (8, 9). Using this information, lines representing equal delivered costs for Alberta and Gulf Coast methanol were obtained and are displayed in Figure 4. The upper (dashed) line is based upon operating costs including 20% return and the lower line upon breakeven costs. In general Alberta methanol is cheaper than Gulf Coast methanol north of these iso-cost lines. Obviously the market determined using a breakeven analysis represents the maximum possible, therefore, this will be the base case. Under the conditions assumed, Alberta methanol captures only a small part of the Northwest U. S. market and none of the market in eastern Canada. The cross-hatched area shown represents the overlap of the breakeven iso-cost line with the Northwest market area, or about 1/3 of the market. Therefore, the market for Alberta methanol in the Northwest would be 1/3 of the 530 million pounds required at the existing formaldehyde plants, or about 180 million pounds. The total Canadian market would be only 150 million pounds, therefore all of the production from one Alberta methanol plant could not be disposed of under the base case assumptions. Before a major methanol industry could be established in Alberta, the parameters affecting the market must be changed.

One of the major factors influencing the price of methanol is the cost of natural gas. Therefore, the market penetration could be

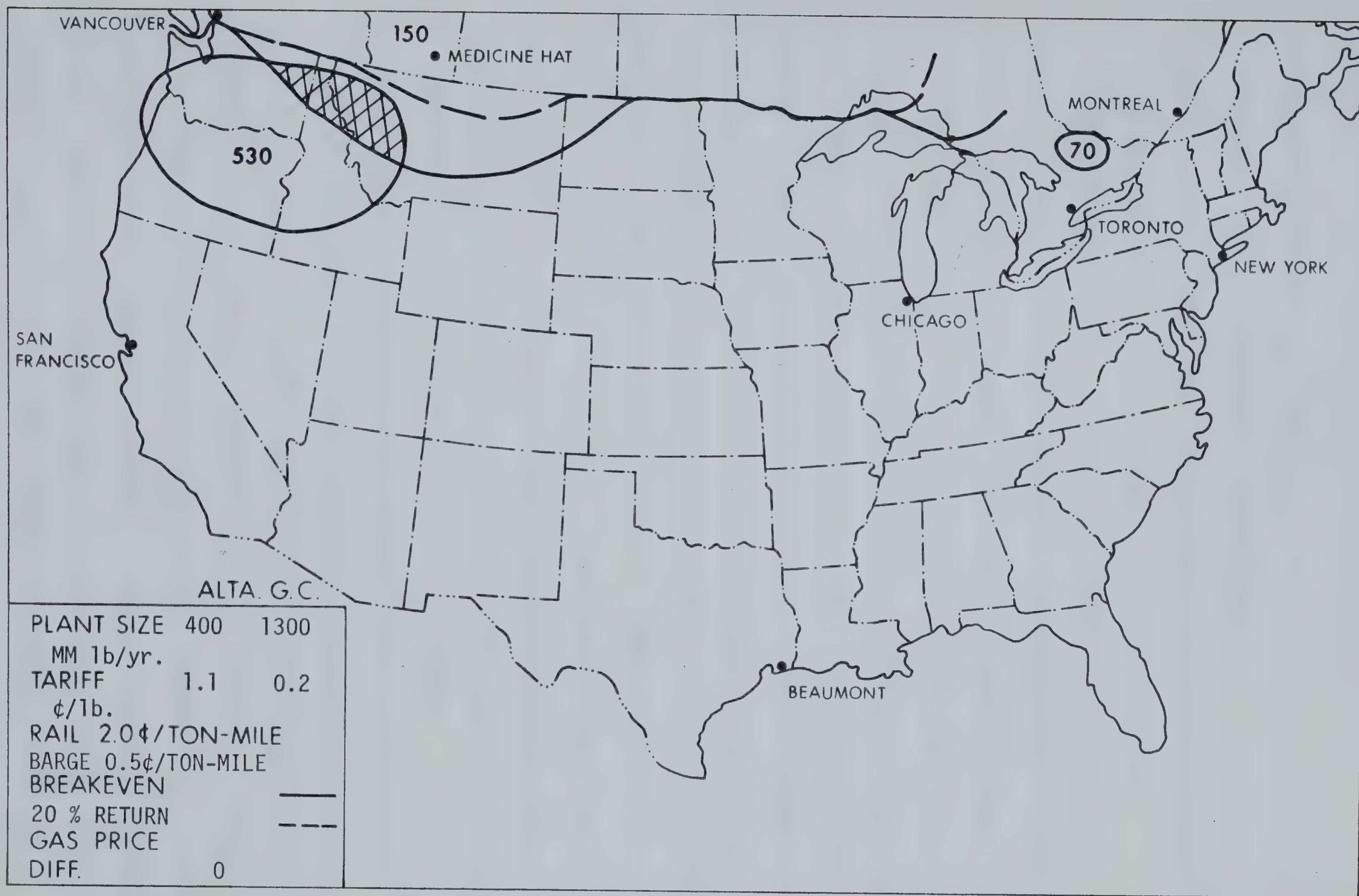

Figure 4. Methanol Base Case Market

increased by maintaining a natural gas price advantage to the Alberta manufacturer over his counterpart in the Gulf Coast. The areas of market penetration using a variety of natural gas differentials for the two producing areas were calculated using the data from Table 5. The results are illustrated in Figure 5. A 50¢/Mcf gas price advantage allows Alberta methanol to be competitive in almost the entire Northwest U.S. market, but does not expand the eastern Canadian market appreciably. Similarly, a $1.00/Mcf natural gas price advantage does not expand the potential market in the U.S. beyond that for 50¢ gas, but Alberta methanol could capture the Canadian market west of Montreal. The total market given a $1.00/Mcf advantage would be about 800 MM lbs, or the production of two Alberta-sized plants. The significant point about this figure though, is that no penetration whatsoever is made into any area in the U.S. other than the Pacific Northwest. Obviously the prospect of cheaper methanol and secure source of supply may encourage methanol users to move into this area thereby increasing the market in the future. The range of gas price differentials selected from 0 to $1.00/Mcf, is extreme. However, the use of a dollar differential is somewhat justified in that synthetic gas from coal, which would represent the upper bound on U.S. natural gas price, is expected to be $1.25 - $1.50/Mcf by 1980 (17). Alberta wellhead prices are expected to be 50¢ - 60¢/Mcf in 1975 (18), although the exact prices are not known, therefore the $1.00/Mcf differential would represent a possible advantage to the Alberta producer. Hereafter, to provide a perspective on the effect of natural gas prices coupled with the other factors, two cases will be analyzed: one with a 0 price differential and one with a $1.00/Mcf

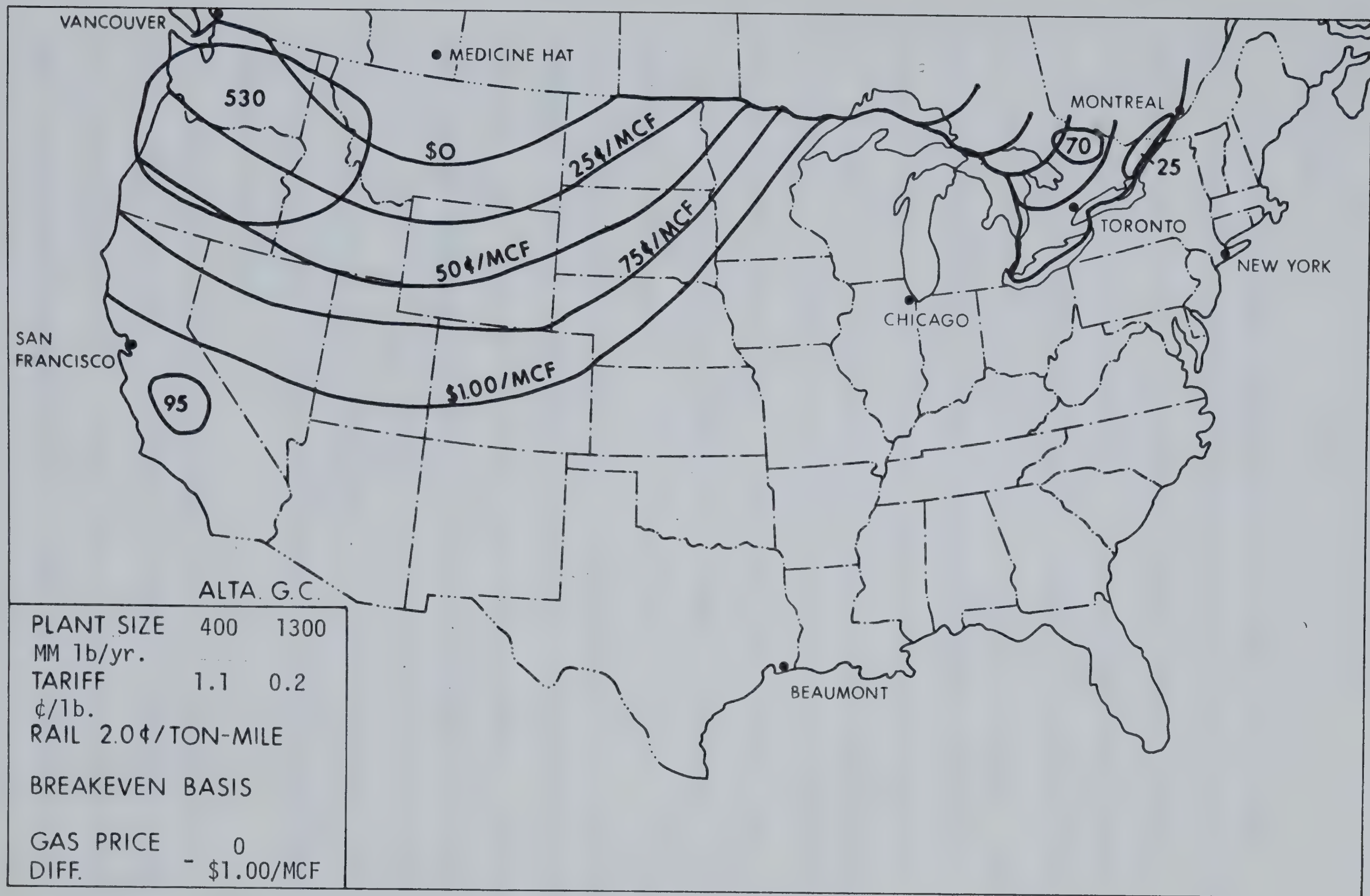

Figure 5. Effect of Gas Price Differential on Methanol Market

differential.

Two of the paramount reasons why large plants have not been built in Canada to take advantage of economies of scale are the small domestic market and inaccessibility of foreign markets. However, given certain gas price concessions, it has been shown that Alberta-produced methanol could penetrate the Northwest U.S. market. Building larger plants could possibly expand the potential market. The manufacturing costs for various sized Alberta methanol plants are shown in Table 6. From this table, the market for each plant size for the zero and dollar gas price differentials was calculated, and is displayed in Figure 6. Plant sizes of 400, 600, and 1300 million pounds per year are represented. The markets for each are based upon the base case parameters of 2¢/Ton-mile freight, 1.1¢/lb tariff, and breakeven operating costs. Figure 6 shows that building a 1300 pound per year plant would not significantly enhance the market for Alberta methanol under these constraints. In addition, all of the production from this plant could not be sold in the projected markets. The maximum plant size would be dictated by the total consumption in the market area. Therefore, since the base case market for a $1.00/MCF gas price differential would be about 800 million pounds per year, plant capacity could not be more than this, based on existing formaldehyde production facilities.

Another factor affecting market penetration is freight rates. Alberta producers would rely heavily on railways to transport goods to Eastern Canadian and U.S. markets, thus freight charges are important in determining methanol prices in these areas. Recall that in the base case analysis, rail freight rates of 2¢/Ton-mile were

Table 6

Effect of Plant Size on Production Costs

of Alberta Methanol

CAPACITY		400 MM lb/yr	600	1300
FIXED CAPITAL:	$MM	18.9	24.1	37.8
WORKING CAPITAL:	$MM	1.3	2.0	3.4
COSTS		¢/lb	¢/lb	¢/lb
NATURAL GAS FEED		.255	---	---
CATALYST		.065	---	---
FUEL		.154	---	---
ELECTRICITY		.028	---	---
BOILER FEED WATER		.003	---	---
		.505	.505	.505
LABOR		.064	.040	.019
MAINTENANCE		.165	.140	.101
OVERHEAD		.172	.048	.024
TAXES		.071	.060	.043
SALES		.048	.042	.032
	BREAKEVEN	.93 ¢/lb	.83 ¢/lb	.72 ¢/lb
DEPRECIATION		.473	.401	.284
PROFIT		1.010	.872	.625
	F.O.B. PLANT	2.42 ¢/lb	2.10 ¢/lb	1.63 ¢/lb

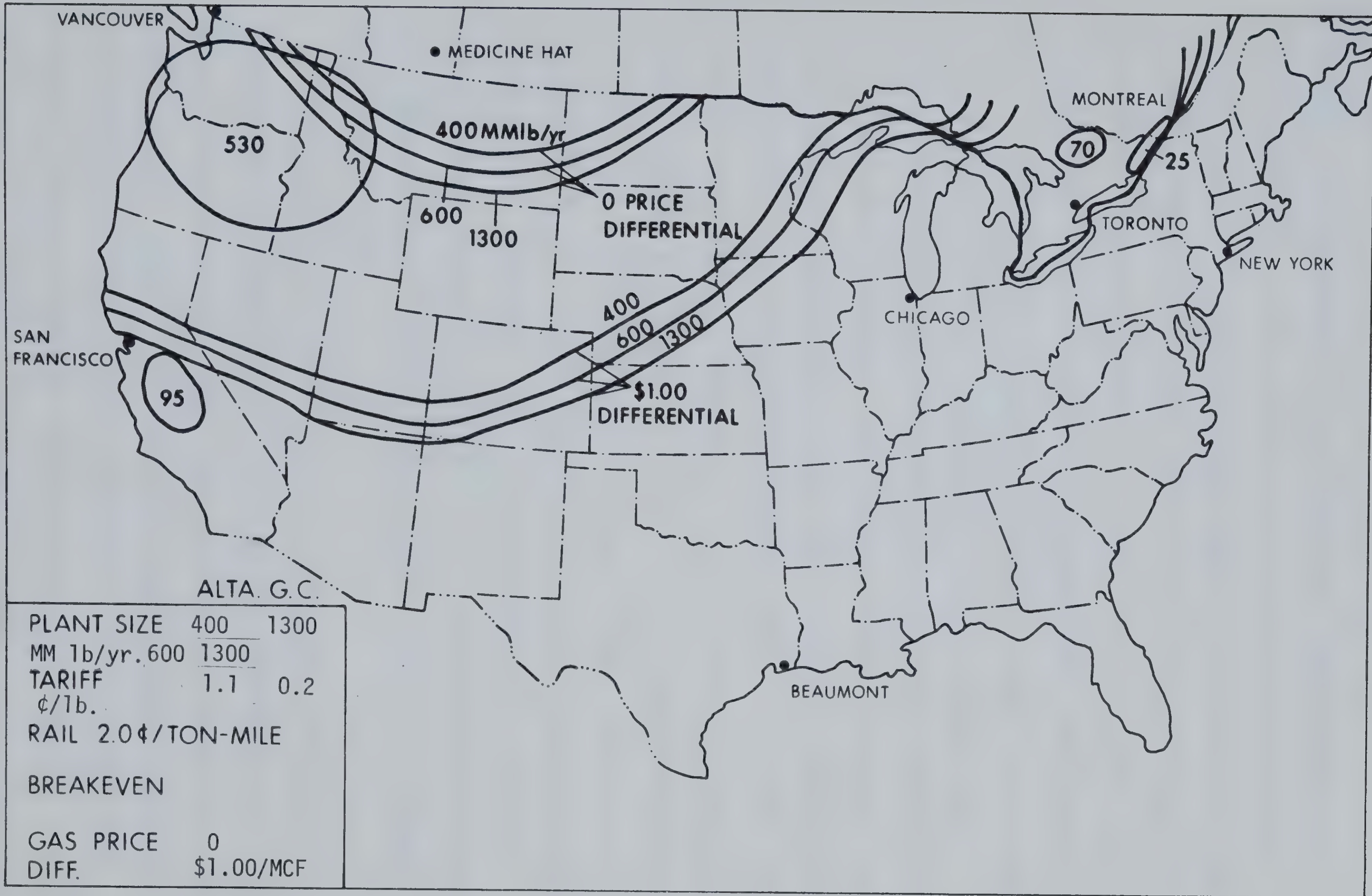

Figure 6. Effect of Plant Size on Methanol Market

assumed. Typical charges for unit trains over long distances are 1¢/Ton-mile(10), therefore the base case market was recalculated using this rate. Changing only this variable, the markets for a 400 MM lb/yr Alberta methanol plant for the two gas price differentials would shift as shown in Figure 7. The solid lines represent freight rates of 2¢/Ton-mile; the dotted lines 1¢/Ton-mile. From this diagram it is apparent that the only new markets in which Alberta methanol would be competitive are the California and Wisconsin areas. Alberta methanol would also capture the entire Canadian market, given a $1.00 gas price advantage. The increased market, as compared to the base case, would be about 180 million pounds annually. Although the geographical area in which Alberta methanol would be competitive has increased substantially, the methanol users in the area represent only a small fraction of the total U.S. market. It is interesting to note that with such rail freight charges, Alberta methanol could not be exported to the U.S. if gas prices in both areas were equal, as shown in the figure. Of course, this is contingent upon U.S. producers having an equal decrease in freight rates. Because of the high tariffs imposed on U.S. imports, Alberta methanol would not be competitive in U.S. markets.

From the analysis to this point, it is apparent that even if Alberta methanol producers had a $1.00 gas price advantage over Gulf Coast producers, no major markets could be penetrated other than the Northwest U.S. Because it is landlocked, Alberta producers cannot take advantage of low-cost water transport as can Gulf Coast manufacturers. However, methanol could be economically pipelined to major U.S. markets. The effect of this mode of transport on the base case

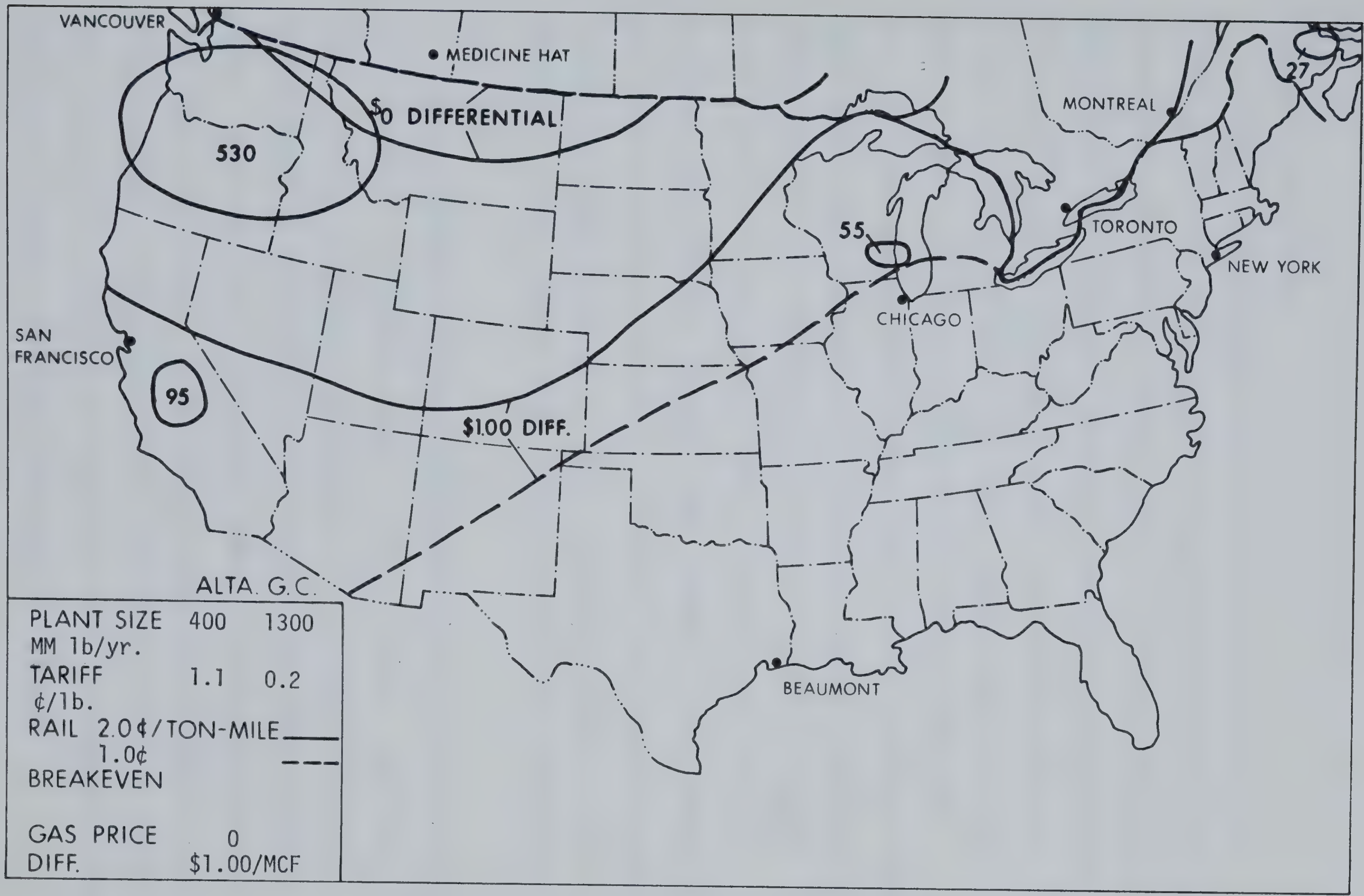

Figure 7. Effect of Rail Freight Rates On Methanol Market

market will be examined.

A commodity pipeline from Alberta to Ohio with connections to eastern Canada from Alberta has been proposed (19), and since this study investigates the effects of various factors on market penetration, the pipeline will be considered. Transmission charges for this pipeline, which would be about 2000 miles in length, were derived from tables in the Oil and Gas Journal (20). The article showed pipeline transport costs of \$1.60 - \$2.10/bbl for this distance would be applicable. This translates into a charge of about 0.6¢ - 0.8¢/lb of methanol shipped. These numbers are approximate, but if methanol could be transported for these costs, the Ohio-New Jersey industrial areas would be feasible outlets for Alberta methanol, as shown in Figure 8, given at least a \$1.00 gas price advantage over Gulf Coast producers. This expansion would result in an increased market of over a billion pounds, just for formaldehyde requirements alone. Thus a commodity pipeline to the eastern U.S. could enable a large methanol industry to be established in Alberta.

Another alternative to rail shipping would be to pipeline methanol to Vancouver and then via tanker to foreign markets. The transmission charges to Vancouver by pipeline would be about 0.3¢/lb (20). Tanker charges to the California coast from Vancouver would be about 0.3¢/lb, which would thus be a cheaper method of methanol transportation than by unit train. The California market would be captured by Alberta producers given a 50¢ gas price advantage, as shown in Figure 9, which would not be possible when shipping by rail. The more significant point about a methanol pipeline to Vancouver is that this

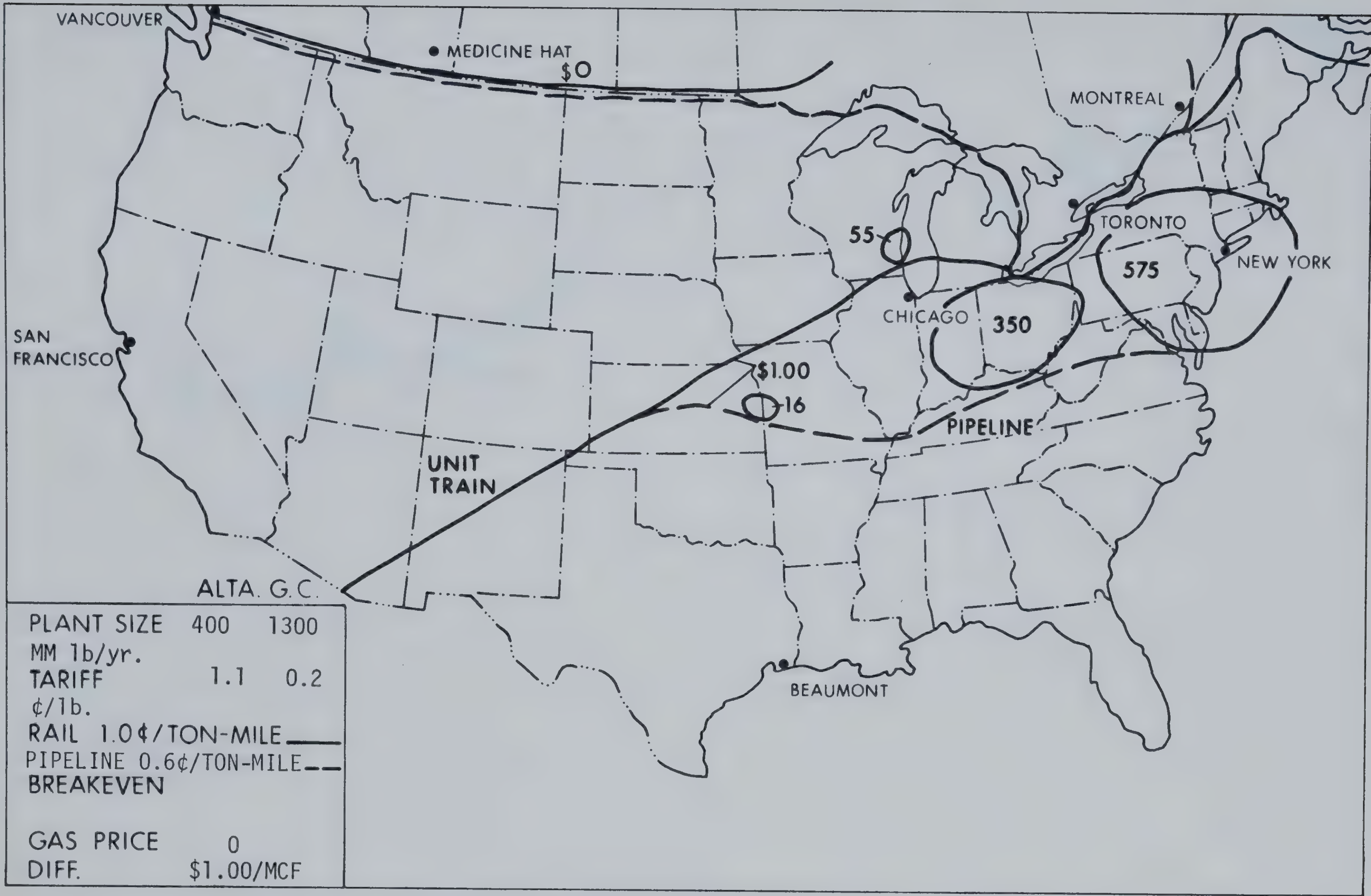

Figure 8. Effect of Ohio Pipeline on Methanol Market

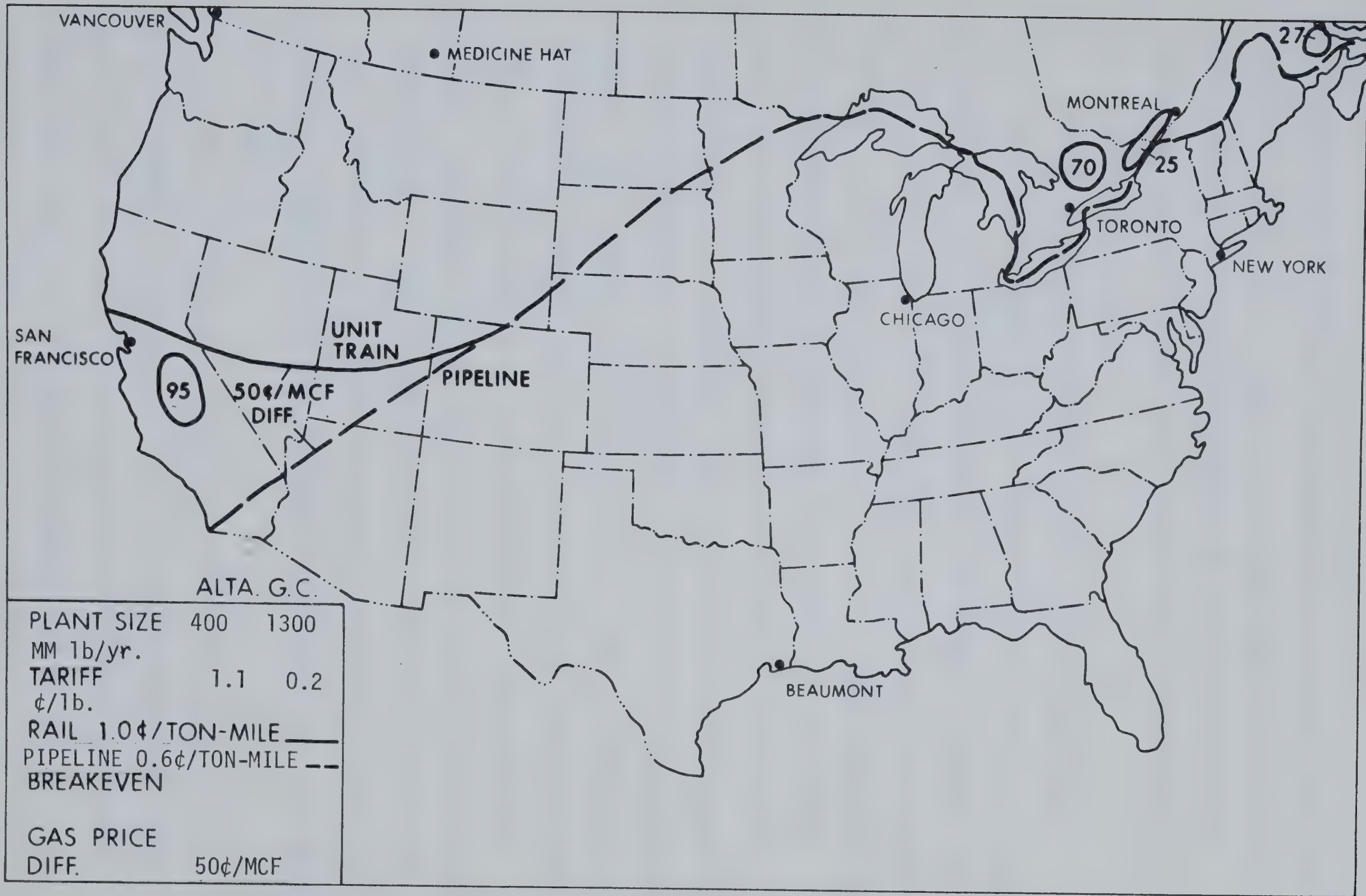

Figure 9. Effect of Vancouver Pipeline on Methanol Market

may enable Alberta methanol to be competitive in markets other than the U.S., such as Japan. However, shipping methanol from Vancouver would still not enable Alberta methanol to penetrate Eastern U.S. markets. A commodity pipeline to these markets would appear to be a more feasible alternative.

Another of the major factors affecting market penetration is the 1.1¢/lb tariff levied on U.S. methanol imports. This tariff poses a strong barrier to exports of methanol from Alberta. However, negotiations are currently taking place which could result in the reduction of tariffs on chemicals imported to the U.S. (GATT negotiations). If the tariff was removed, the base case markets for the zero and dollar gas price differentials would be represented by the solid lines shown in Figure 10. The dotted lines designate the base case markets including the tariff. As illustrated, the market for Alberta-produced methanol would encompass all areas north of a line stretching from New Mexico to Michigan, under the constraints of 2¢/Ton-mile freight rates, no tariff restrictions, and $1.00/Mcf gas price advantage. However, the actual methanol market expansion would be less than 200 million pounds. A more significant increase occurs for the zero gas price differential. As shown, removing the tariff would allow Alberta methanol to capture the entire Northwest U.S. market, even with no gas price advantage.

However, at these freight rates, Alberta methanol would not penetrate eastern U.S. markets, even with no tariff restrictions. The market lines were therefore recalculated using 1¢/Ton-mile freight rates, again using zero tariffs. The results for the two gas price differentials are shown in Figure 11. Lower freight charges have very

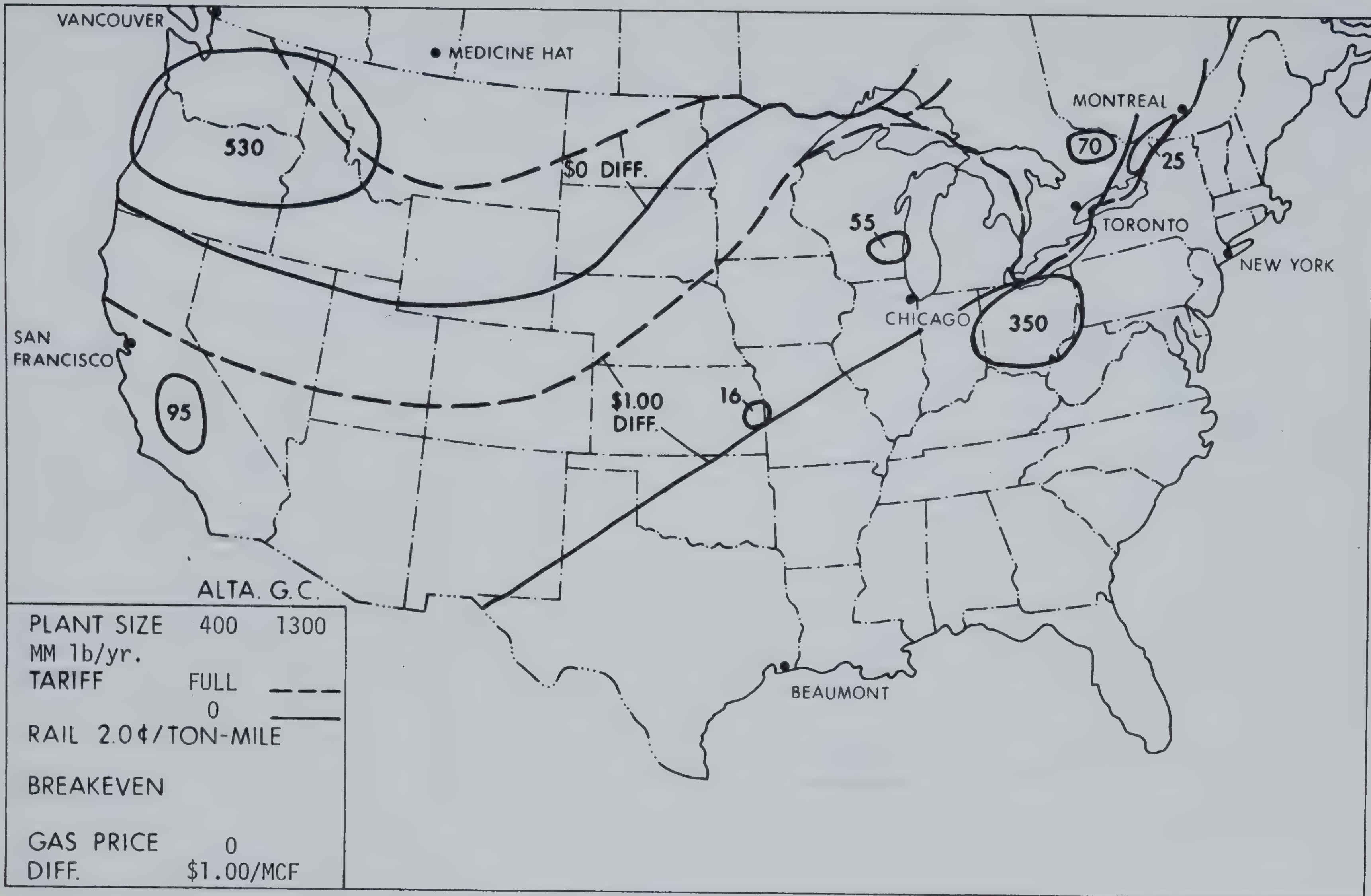

Figure 10. Effect of Tariffs on Methanol Market

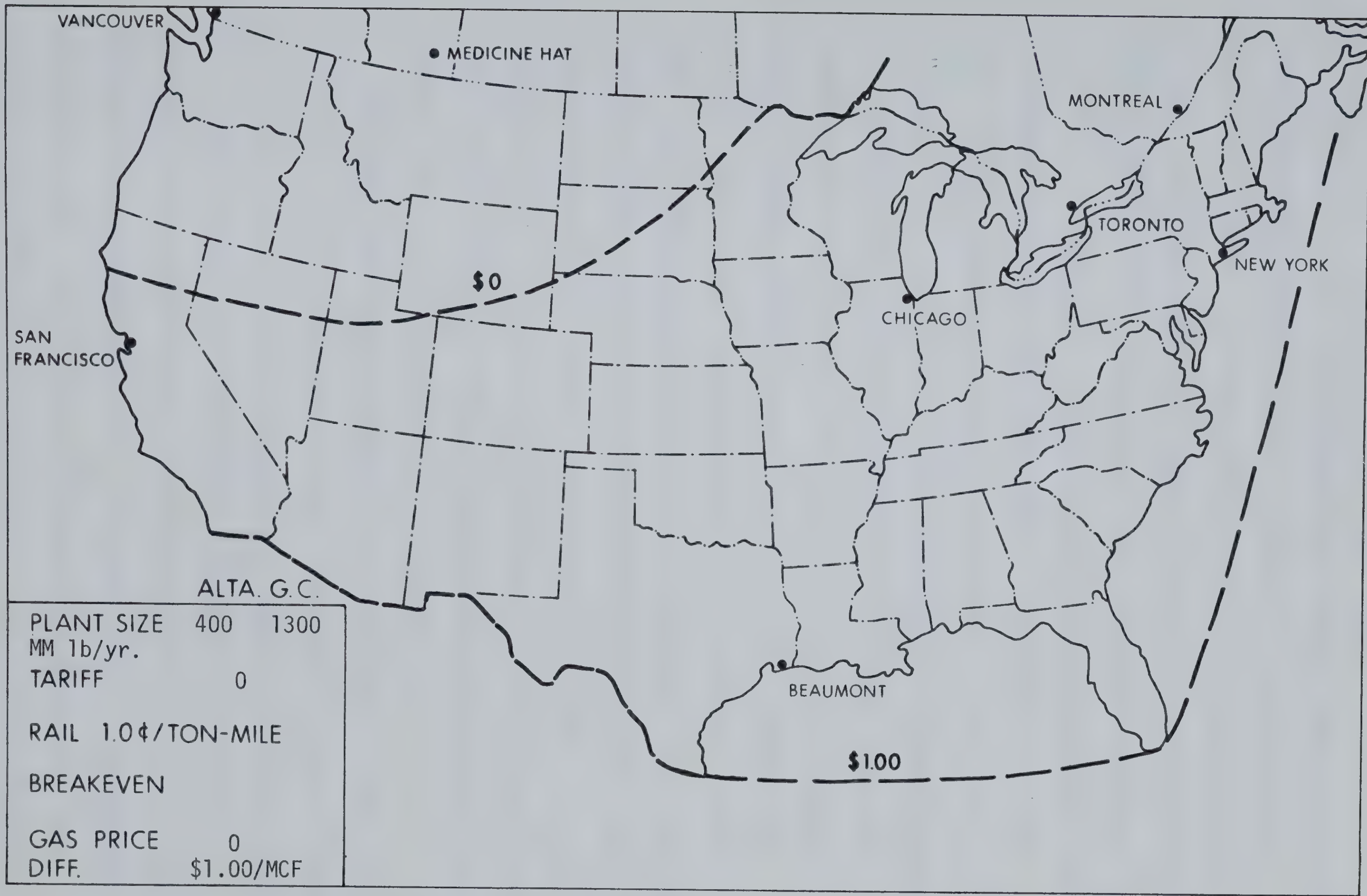

Figure 11. Effect of Tariffs and Freight Rates on Methanol Market

little effect on the 0 price differential case, but these rates would enable Alberta methanol to capture the entire U.S. market if the tariff was removed and Alberta producers had a dollar gas price advantage. This would obviously represent the maximum penetration into the U.S. market, which consumed over 7 billion pounds of methanol in 1973 (21). Of course it is highly unlikely that the methanol industry in Alberta would ever satisfy this demand. Six Texas-sized plants would be required, consuming over 130 billion cu. ft. of natural gas annually. This is about 1/5 of the total Canadian industrial consumption of natural gas, using 1972 estimates (22). This level of consumption solely for methanol production could not possibly be maintained. Although several plants of the size of the proposed 400 million pound per year complex could be built in Alberta, the exact number would depend upon the factors already examined; that is whether Alberta producers had a natural gas price advantage over Gulf Coast producers, what freight charges would be levied, and what the tariff structure will be. The Provincial Government will have ultimate control over the industry, of course, because proposals which would use Alberta natural gas must be approved by the ERCB (23).

One other factor affecting market penetration has not been discussed and that is the problem of natural gas supply. Values of methanol price for various levels of natural gas supply are shown in Table 7. As shown, natural gas supply does not appreciably affect the breakeven price of methanol and thus would not affect the market line based upon price comparisons alone. The market will be dictated more by methanol supply than by price. For example, a uniformly distributed 25% gas shortage to the industrial U.S. consumer would imply a

Table 7

Effect of Natural Gas Supply on Gulf Coast Methanol Prices

PLANT SIZE: 1300 MM lb/yr

PRODUCTION LEVEL		100%	75%	50%
FEED	\$1.00/MCF	1.020	---	---
CATALYST		.065	---	---
ELECTRICITY		.028	---	---
FUEL	\$1.00/MCF	.604	---	---
BOILER FEED WATER		.003	---	---
		1.720	1.720	1.720
LABOR		.019	.023	.036
MAINTENANCE		.083	.104	.166
OVERHEAD		.023	.028	.046
TAXES		.035	.045	.072
RESEARCH AND ADMINISTRATION		.054	.060	.075
BREAKEVEN COST (TOTAL)		1.93 ¢/lb	1.98 ¢/lb	2.116 ¢/lb
DEPRECIATION		.236	.295	.472
PROFIT		.566	.710	1.140
F.O.B.		2.73 ¢/lb	2.99 ¢/lb	3.73 ¢/lb

75% methanol production level. This would represent 1.8 billion pounds of methanol shortage if this level had to be maintained for a year. Whichever areas were short of methanol supplies could be potential Alberta methanol consumers. The problem of natural gas supply merits further investigation and will form the basis of Chapter VII in this study. From forecasts of natural gas supply and demand, future chemical prices will be determined, and from these results, industrial gas prices in the U.S. will be predicted.

From the preceding analysis, it is apparent that large volumes of Alberta methanol could be exported to U.S. markets, given a substantial gas price advantage and reduction of tariffs. Other foreign producers will also be able to export to the U.S. if these countries have an abundant supply of low-cost natural gas. The Middle East represents potentially the largest competitor and several petrochemical complexes have been proposed for the area (24). One of the proposed methanol plants would have a capacity of 10,000 Tons/day (25), or five times the capacity of the largest Texas plant. The market penetration by production from a plant of this size will be examined.

Table 8 shows the production costs of a 10,000 T/day methanol plant producing in the Middle East.

Gas costs were assumed zero since gas is currently being flared. Capital costs were obtained from estimates by Davis (25). All other production costs were assumed equivalent to Alberta (6) except taxes and insurance, which, because developments may be government owned, were assumed negligible. The breakeven cost of methanol produced at this plant would be about 0.2¢/lb under these constraints. Methanol would be transported from the Middle East by large crude oil

Table 8

Middle East Methanol Production Costs

FEED: NATURAL GAS

CAPACITY: 10,000 T/DAY

FIXED COST $MM 118.0

WORKING: $MM 7.5

			¢/lb
NATURAL GAS		@	$0.0
CATALYST			0.065
FUEL		@	$0.0
ELECTRICITY			0.028
BOILER FEED			0.003
LABOR			0.004
MAINTENANCE	3.5% FIXED		0.163
OVERHEAD			0.025
TAXES			0.0
DEPRECIATION	10% FIXED CAPITAL		.179
SALES	2%		.015
PROFIT	20% TOTAL		.380
	F.O.B. PRICE		.74 ¢/lb
	BREAKEVEN PRICE=		.18 ¢/lb

tankers. For purposes of price determination, a 1972 National Petroleum Council (2) estimate of \$9/L.Ton for crude transport from the Persian Gulf to the U.S. East Coast was used. If operating costs are assumed to escalate at 10% per year, transport charges will be about \$14/L.Ton (.6¢/lb) in 1977, at which time the plant could be on stream. Middle East methanol would thus cost 1.9¢/lb along the East Coast, including tariff and freight charges. This price is approximately equal to Gulf Coast prices based on 50¢/Mcf natural gas. Consequently, if Gulf Coast gas prices rise above this level, Middle East methanol could conceivably capture the eastern U.S. market. If shipping costs are extrapolated to the west coast, Middle East methanol could be transported to San Francisco for .8¢/lb. Middle East methanol would cost 2.1¢/lb there. As shown in Table 9, Alberta methanol producers, using 25¢/Mcf natural gas feed, would no longer be competitive in the Oregon formaldehyde market or in southern Ontario, which would represent a market loss of over 500 MM lb.

Table 9

Middle East vs. Alberta Methanol Costs

DESTINATION		PRICE ¢/lb		
		ALBERTA	MIDDLE EAST	
	GAS PRICE	25¢/MCF	0¢/MCF	25¢/MCF
VANCOUVER		1.7	1.3	1.7
SAN FRANCISCO		3.5	2.1	2.5
CHICAGO		2.6	2.3	2.7
TORONTO		2.9	1.3	1.7
SEATTLE		2.9	2.2	2.6

However, the Middle East production costs tabulated represent the minimum values possible. If gas costs were 25¢/MCF in the Middle East, Alberta methanol would be competitive in Chicago, as Table 9 shows. In addition, the construction of the large methanol plant hinges on whether the tariff on methanol is removed. Methanol from this plant may be used as a substitute for liquid natural gas (LNG) because over long distances it is more economically viable (25). This methanol, however, would not be competitive with alternative fuel sources such as synthetic gas from coal unless the tariff was removed. Middle East methanol will have a heating value of $1.30/ MM Btu excluding the tariff, and coal gas costs are expected to be about the same in the late 1970's (17). If the tariff was removed, however, Middle East methanol could force Gulf Coast producers out of the U.S. market. Therefore, the tariff would probably only be removed for methanol destined for SNG production.

Hence, Middle East methanol could capture the Oregon formaldehyde market. However, this would occur only if the production of a 10,000 Ton/day methanol plant with zero feedstock costs entered this market. The Alberta methanol industry would not be able to export methanol to U.S. markets, except in the interior of Washington and Montana.

There is a great potential for development of a major methanol industry in Alberta, depending upon what the various parameters affecting market penetration will be. The cases analyzed reflect the effect of these factors on the market for Alberta-produced methanol, but no conclusions have been made regarding which case would be applicable.

CHAPTER IV

AMMONIA MARKET ANALYSIS

Ammonia is one of the most important chemicals produced in North America. Production of anhydrous ammonia reached 31 billion pounds in the U.S. in 1973 (21) and 2.7 billion pounds in Canada, of which over 140 million pounds were exported to the U.S. (26). Obviously, Canadian ammonia is presently competitive in some U.S. markets. This situation has developed because Gulf Coast plants, although larger than those in Canada, do not have significantly lower production costs. In addition, there is no tariff on ammonia used for fertilizer, the primary use for the chemical. Rising U.S. gas prices will probably further enhance the Canadian position in U.S. ammonia markets.

The prospect of relatively inexpensive and secure gas supplies in Alberta coupled with the existing tariff structure has prompted several proposals by chemical companies to build ammonia plants in southern Alberta (3). This study examines the market for Alberta-produced ammonia and sensitivity of the market to changes in natural gas price and supply, plant size, and freight rates. Market sensitivity to tariffs will obviously not be determined. The analysis will parallel that used in the methanol study but omitting this factor.

The principal use for ammonia is as a direct application fertilizer. Ammonia derivatives, such as ammonium nitrate, phosphate, sulfate, and urea are also used mainly in fertilizers. Ammonia consumption is thus directly related to the farming industry. Consequently, ammonia production should be concentrated in the U.S. Midwest,

where the farming industry is located. However, Figure 12 shows that although this area has a large ammonia capacity, the majority of the U.S. industry is located in Texas and Louisiana. Ammonia capacity in each area is represented in the figure in thousands of tons per year (15, 16).

This concentration of chemical capacity along the Gulf Coast is due to the availability of low-cost natural gas in this area. Large volumes of Gulf Coast production are shipped via barge and pipeline to the Midwest, which is the major consumer of ammonia, as illustrated in Figure 13. Ammonia consumption in each area is designated in thousands of tons (15, 19). It should be noted that the numbers shown in the figure were estimated from historical production and consumption data and reflect only the major uses for ammonia. For this reason, total consumption shown is slightly less than reported 1973 production. Canadian figures are based upon a 87% production level, which was determined from capacity and production data from 1973 (26). It should also be noted that less than 1/2 of Canadian wheat and rapeseed crops were fertilized in 1972 (27), therefore, actual ammonia consumption could possibly be much greater if increased fertilization of crops occur. The data on this figure thus shows the present major market areas for ammonia in North America.

The base case for the ammonia study will compare a 1500 Ton/day Alberta plant, which is equal in size to one of the proposed plants, and a similar-sized Gulf Coast plant. At present, 1500 Ton/day is the largest single-train ammonia plant producing in North America (15). Market penetration is assumed to be determined by cost of ammonia only. The cheapest supplier to an area would capture the

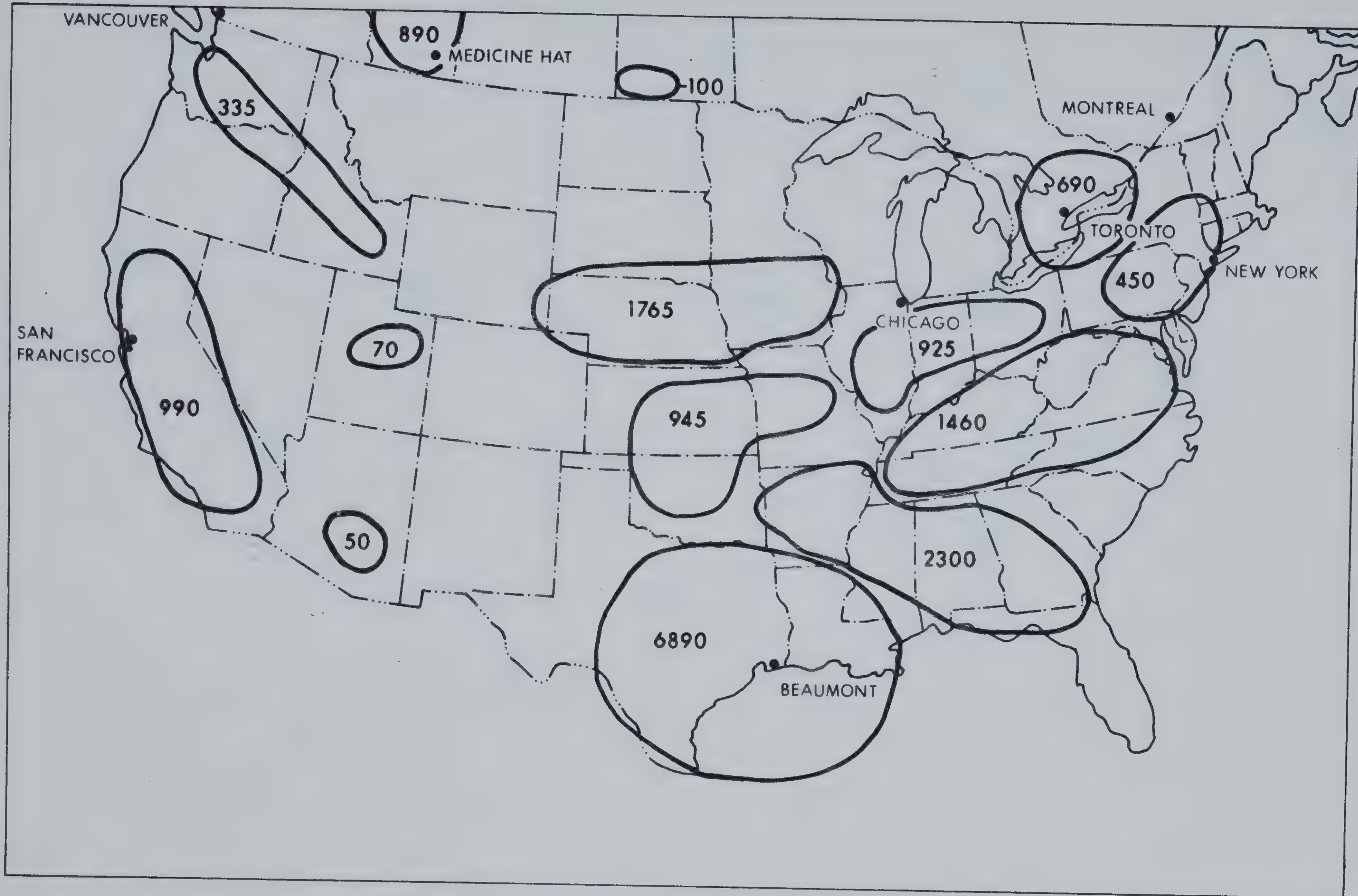

Figure 12. Ammonia Capacity (1000's of Tons)

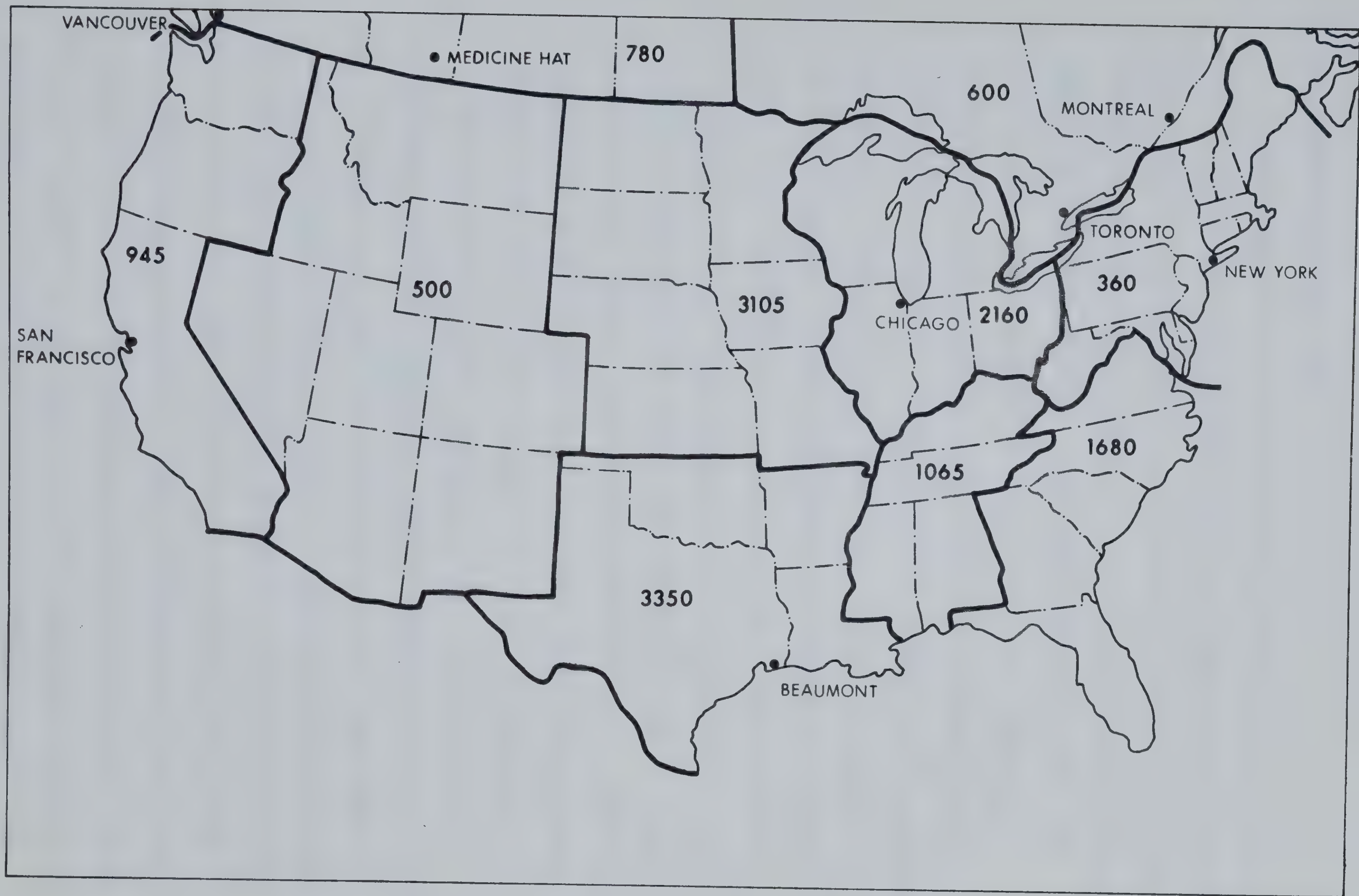

Figure 13. Ammonia Consumption (1000's of Tons)

entire market in that area.

Production costs for an Alberta and a Gulf Coast plant (6) are shown in Table 10. Using 25¢/Mcf natural gas feed, Alberta could produce ammonia for a breakeven operating cost of 0.8¢/lb. Gulf Coast producers would have approximately the same production costs, using natural gas at the same price. Using these production costs, and assuming base case parameters of 2.0¢/Ton-mile rail charges and 0.5¢/Ton-mile barge rates, the market line was determined, and is illustrated in Figure 14. As shown, Alberta ammonia would capture the Northwest U.S. market plus western Canada. Present consumption in this area is about 2 million tons annually or roughly the production of four large ammonia plants. Because there is no tariff barrier to U.S. imports (8), the market determined under the base case constraints is much larger for ammonia than methanol. Ammonia consumption is also more evenly distributed throughout the U.S., rather than concentrated in two or three areas. For this reason, the establishment of a much larger ammonia industry in Alberta is possible.

From studying the base case market line, it is apparent that the Midwest U.S. market would be a potential outlet for Alberta ammonia if producers had a gas price advantage over Gulf Coast manufacturers. Gulf Coast production costs were recalculated for a variety of natural gas prices to determine the effect of gas price differential on market penetration. From these calculations, the markets for Alberta-produced ammonia for gas price differentials from zero to one dollar per MCF were determined, and are represented in Figure 15. As illustrated in the figure, a 50¢/Mcf advantage to Alberta producers would expand the base case market to encompass most of the

Table 10

Anhydrous Ammonia Production Costs

		ALBERTA	GULF COAST
CAPACITY	MM LB/YR	1050	1050
FIXED CAPITAL	$MM	48.8	40.3
WORKING CAPITAL	$MM	4.0	3.2
		¢/lb	¢/lb
NATURAL GAS @	$.25/MCF	.260	.260
CATALYST		.036	.036
ELECTRICITY		.010	.010
PROCESS WATER		.008	.008
COOLING WATER		.005	.005
FUEL @	$.25/MCF	.175	.175
LABOR		.028	.028
MAINTENANCE		.139	.115
OVERHEAD		.033	.033
TAXES		.071	.058
DEPRECIATION		.462	.384
SALES		.045	.040
PROFIT		1.000	.828
	PLANT GATE PRICE	2.272	1.980
	BREAKEVEN PRICE	0.81 ¢/lb	0.77 ¢/lb

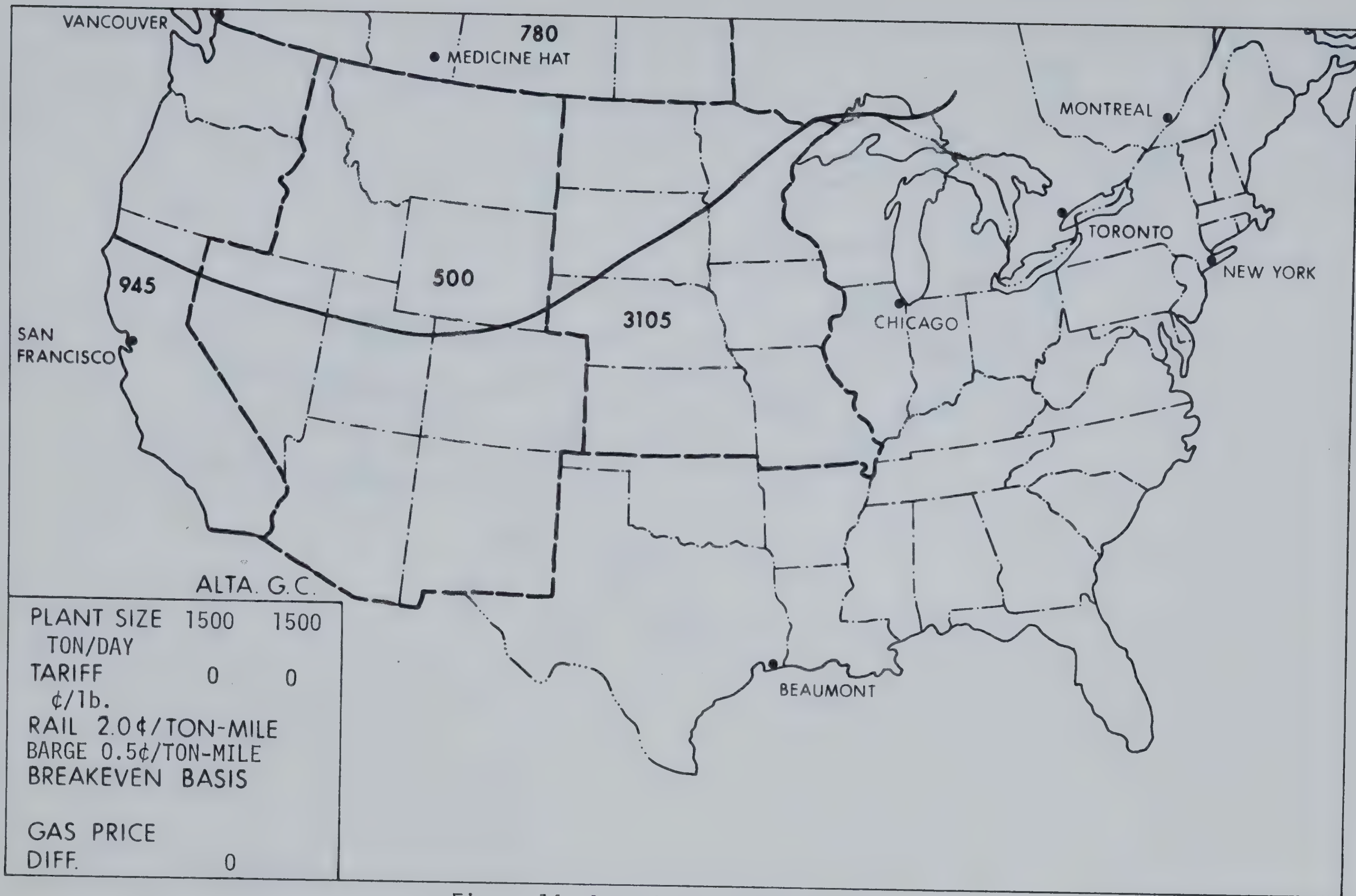

Figure 14. Ammonia Base Case Market

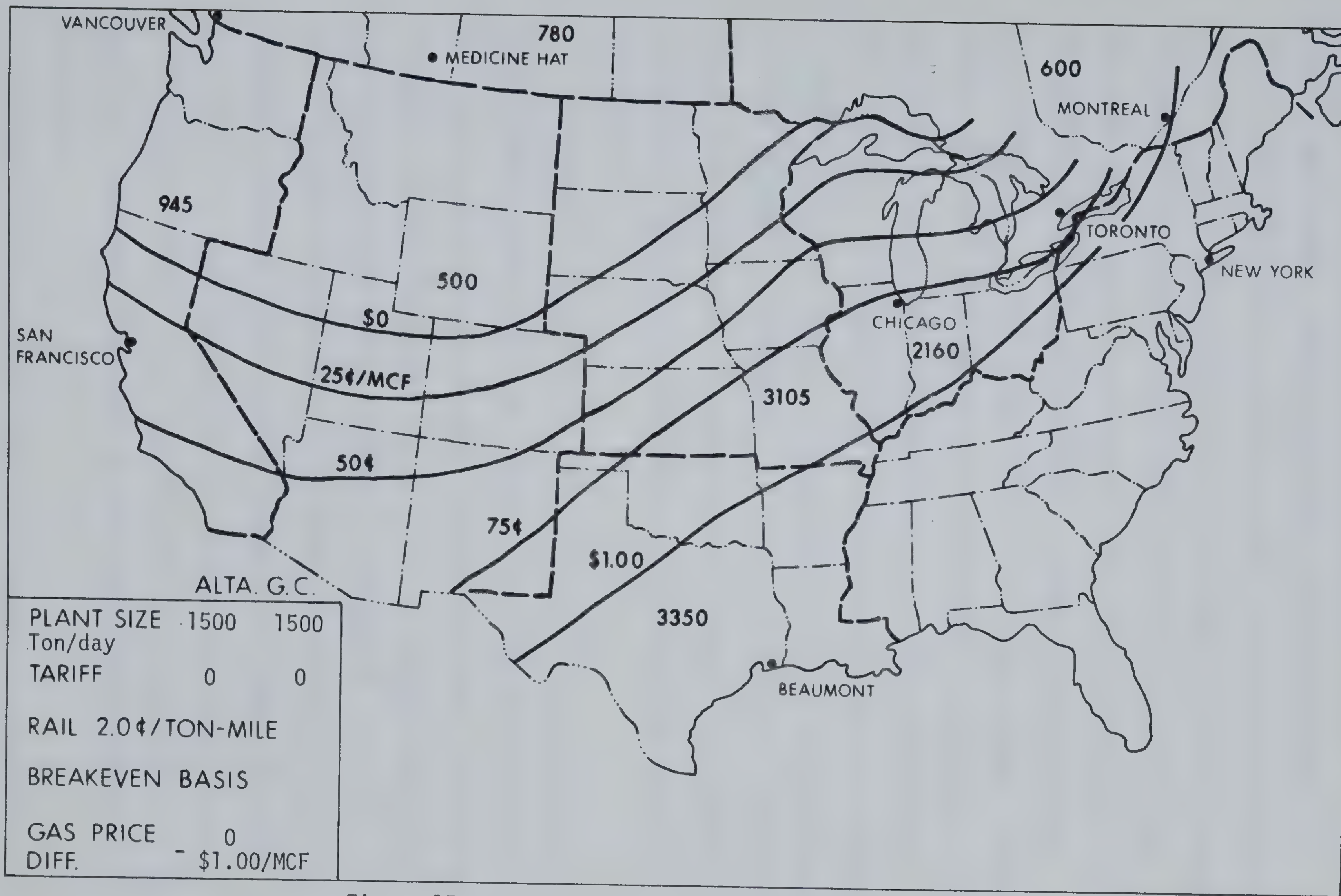

Figure 15. Effect of Gas Price Differential on Ammonia Market

Pacific and Mountain regions, plus about 1/2 of the Mid-West U. S. market. No significant penetration is made into the eastern Canadian market, however. This expansion would be roughly 1.5 million tons/year or equal to the production of 3 large ammonia plants. A $1.00/Mcf advantage would enable Alberta manufacturers to be competitive in the Great Lakes area plus eastern Canada, a further increase of about 4.5 million tons, or nine ammonia plants of the size studied. The total market for Alberta ammonia, under the constraints of 2¢/Ton-mile freight and $1.00 gas price advantage, would thus be in excess of 8 million tons annually. The potential for a large ammonia industry in Alberta is therefore almost limitless, given a substantial gas price advantage to local producers. Henceforth, to provide a perspective on the effect of gas price differential coupled with other factors, two cases will be analyzed: the zero gas price differential and the one dollar differential.

The effect of plant size on market penetration is much less definitive than natural gas price. Table 11 shows the production costs for Alberta ammonia plants of 1000, 1500 and 2500 T/day. The markets for ammonia produced by plants of this size, for the zero and dollar gas price differentials, are represented in Figure 16. As shown, plant size does not appreciably affect market penetration, based on breakeven production costs. However, using f.o.b. production costs, plant size has a much more significant effect on the ammonia market, as Figure 16a illustrates. In a market which is concentrated in a few areas, as is methanol, the effect of plant size would be even more significant.

Freight rates is another factor affecting market penetration.

Table 11

Effect of Plant Size on Ammonia Production Costs

Basis: Alberta

PLANT SIZE	MTON/yr	350 (1000 T/D)	525 (1500 T/D)	875 (2500 T/D)
FIXED CAPITAL	$MM	38.0	48.8	68.0
WORKING CAPITAL	$MM	2.8	4.0	5.4
		¢/lb	¢/lb	¢/lb
NATURAL GAS FEED @25¢/MCF		---	.260	---
CATALYST		---	.036	---
FUEL		---	.175	---
ELECTRICITY		---	.010	---
PROCESS WATER		---	.008	---
COOLING WATER		---	.005	---
		.494	.494	.494
LABOR		.040	.028	.017
MAINTENANCE		.163	.139	.116
OVERHEAD		.048	.033	.020
TAXES		.081	.070	.058
DEPRECIATION		.543	.462	.378
SALES		.051	.045	.040
PROFIT		1.165	1.000	.840
F.O.B.		2.55 ¢/lb	2.27 ¢/lb	1.96 ¢/lb
BREAKEVEN PRICE		0.88 ¢/lb	0.81 ¢/lb	0.76 ¢/lb

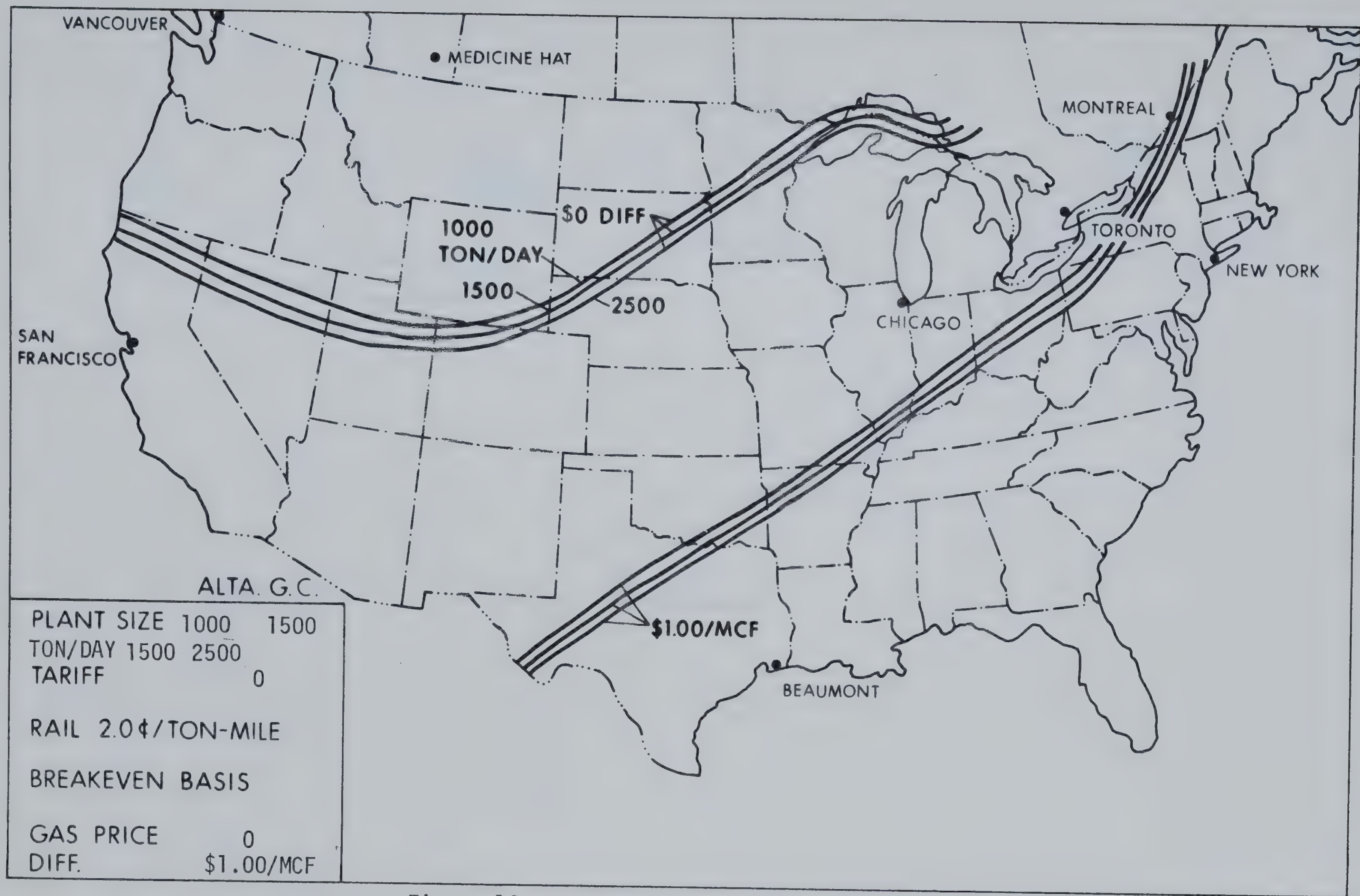

Figure 16. Effect of Plant Size on Ammonia Market

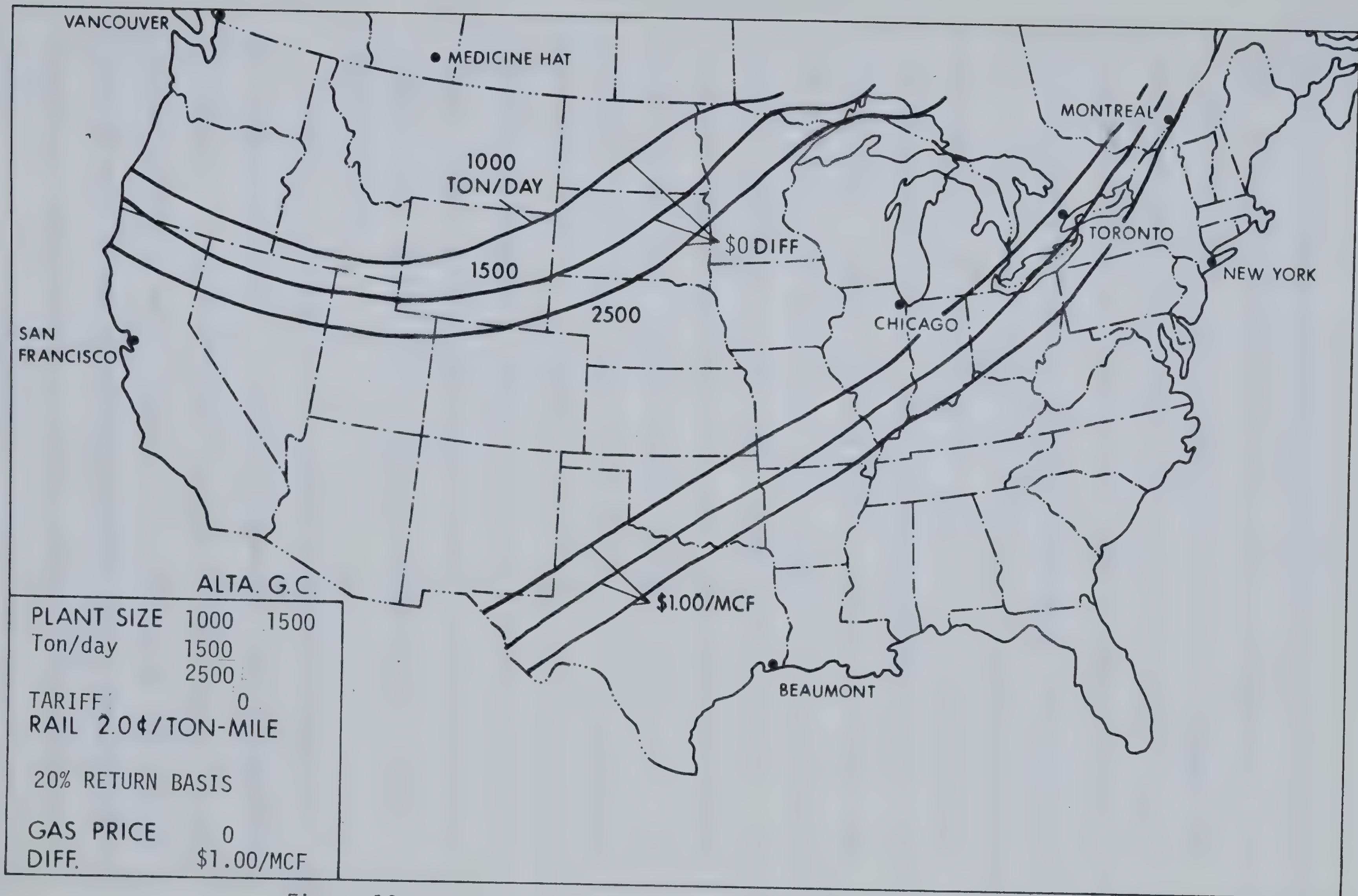

Figure 16a. Effect of Plant Size on Ammonia Market Using FOB Prices

Market lines were recalculated assuming unit train rates of 1¢/Ton-mile, and are represented for the two gas price differentials in Figure 17. The dotted lines designate 2¢/Ton-mile rail charges, the solid lines 1¢/Ton-mile freight. As shown, lower freight rates do not appreciably affect the market for Alberta-produced ammonia given no gas price advantage over Gulf Coast producers. The major expansion occurs in the California and Mid-West U.S. markets, representing an increase of about 1 million tons annually, or the production of two large ammonia plants. It is interesting to note that no significant expansion occurs in eastern Canada. The maximum market penetration occurs for 1¢/Ton-mile freight charges and $1/Mcf differential, as illustrated in the figure. Under these constraints, Alberta producers would be competitive throughout the entire continental U.S., which consumed over 31 billion pounds of ammonia in 1973 (21). To meet this demand would require about 30 plants of the size studied, which would probably not develop because of the large volume of natural gas feed required. However, even with a zero gas price differential, Alberta ammonia could capture about 3 million tons of the North American ammonia market, under the constraint of 1¢/Ton-mile freight charges.

The cost of transporting ammonia to a potential market area thus has a significant effect on whether the product will be competitive in that area. Several companies have argued that since it is much cheaper to pipeline natural gas than ship ammonia by rail, plants should be built closer to potential markets (28). This prompted a proposal by Alberta Ammonia to build a pipeline from southeastern Alberta to Iowa, with connections to Indiana and eastern Canada (19).

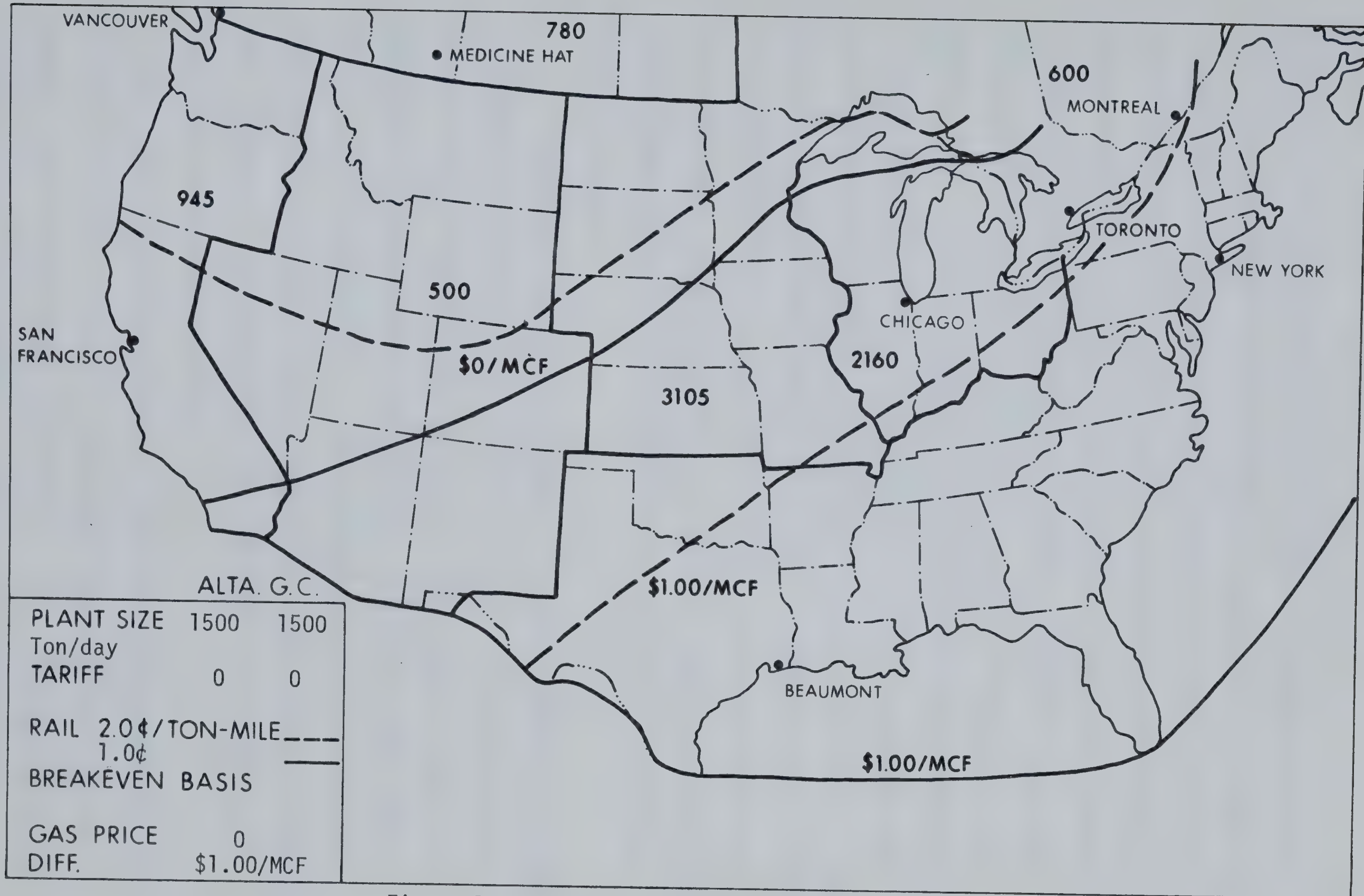

Figure 17. Effect of Freight Rates on Ammonia Market

The effect of such a pipeline on the market line given a 50¢/MCF gas price differential is illustrated by the solid line in Figure 18. Transmission costs were assumed to be 0.7¢/Ton-mile(10). As shown, such a gas price differential would enable Alberta manufacturers to compete in eastern U.S. and Canadian markets. This would represent an expansion of over 4 million tons annually, compared to the base case market for a 50¢/Mcf differential, which is designated by the dotted line. Hence, a large ammonia industry could be established in Alberta, if this pipeline is completed, and Alberta producers had a 50¢/Mcf gas price advantage over their Gulf Coast counterparts. The more significant aspect about this pipeline, however, is that it would not appreciably enhance the market if Alberta producers had no gas price advantage. Barge transport is slightly cheaper than pipeline transmission, thus Gulf Coast product would be cheaper in the Iowa-Great Lakes area.

In conclusion, the market outlook for ammonia produced in Alberta is much more optimistic than for methanol, due to the existing tariff structure. Ammonia producers require a much smaller gas price advantage to secure a large export market. There is a great potential for the development of a major ammonia complex in Alberta, but the Provincial Government will have ultimate control over this development. However, it appears that the construction of a major ammonia industry in Alberta is inevitable.

All of the preceding analysis is based upon the assumption that potential consumers in a market area would buy from the cheapest supplier, thus forcing existing producers in the area out of business if Alberta product were cheaper. However, these producers may

decide to continue operating, albeit with a very small profit margin. This situation could develop if Canadian producers would require a substantial profit before entering a market. Older U.S. plants, having operated for several years and having obtained a good return on initial investment, would not require this large profit margin. The market lines were recalculated comparing U.S. producers operating on a breakeven basis and Alberta producers operating with a 20% investment return, and are designated for the two gas price differentials by the solid lines in Figure 19. As shown, Alberta product would not be competitive in U.S. markets except in Montana and part of North Dakota, given no gas price advantage over Gulf Coast producers. Similarly, the market for a one dollar differential on this basis in only slightly larger than the base case market. Producers within the region between the breakeven and 20% return market lines could conceivably continue operating, but with very small profit margins.

If these plants remained in operation, Alberta producers could only compete for the growth in ammonia consumption within this market area. For example, current consumption in the area between the \$1.00 market lines in Figure 19 is about 5 million tons. The expected growth rate for ammonia is 6 - 8.5% annually(10), thus ammonia consumption in the area could be 1.7 - 2.5 million tons greater in five years. This would necessitate the building of 3 - 5 large ammonia plants to meet this demand. These plants could be built in Alberta because in this region new Alberta production would be more competitive than new U.S. plants. A large ammonia industry could still be established in Alberta even if American producers continued operating, given a \$1.00 gas price advantage over these producers.

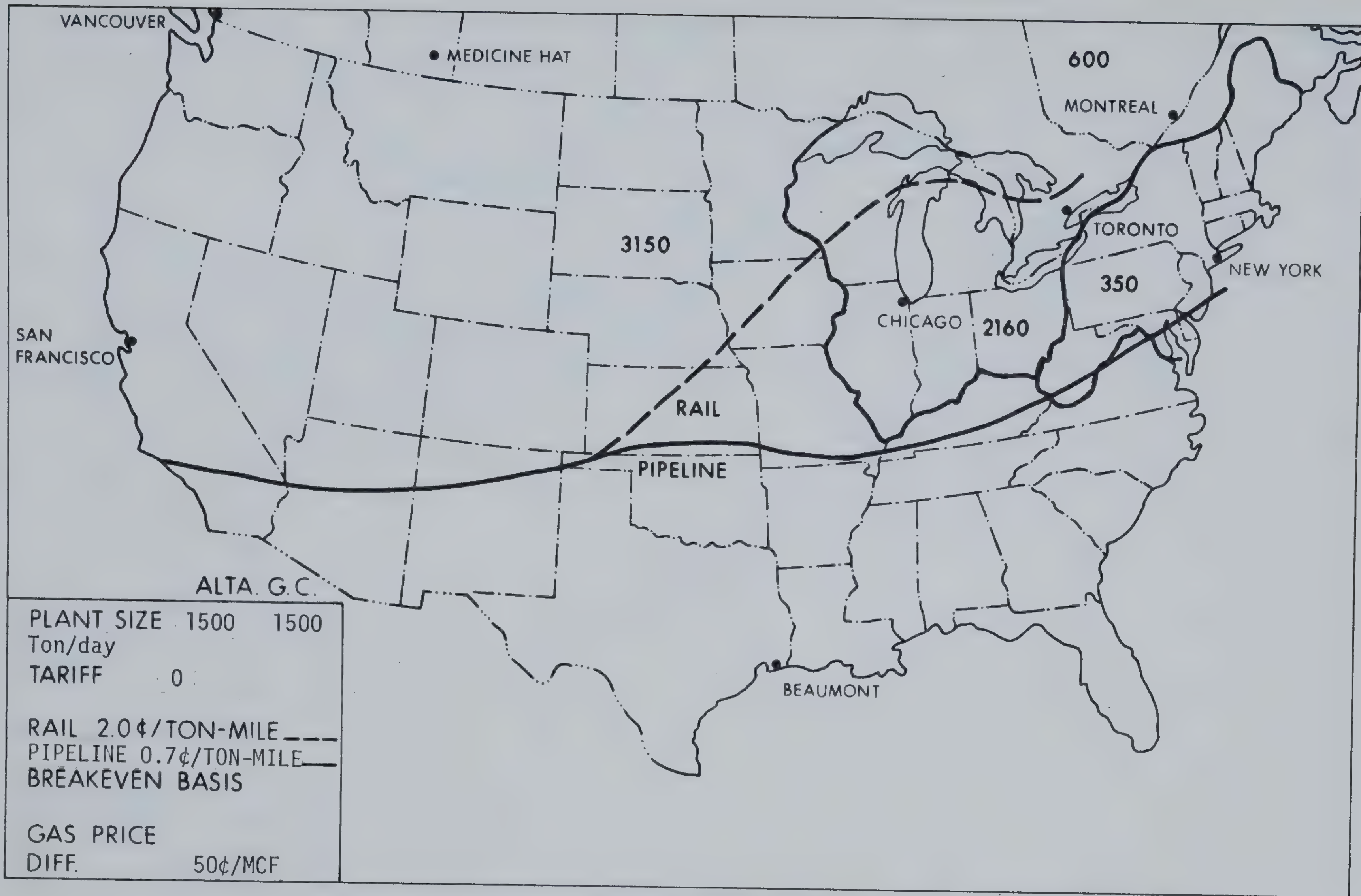

Figure 18. Effect of Commodity Pipeline to Iowa on Ammonia Market

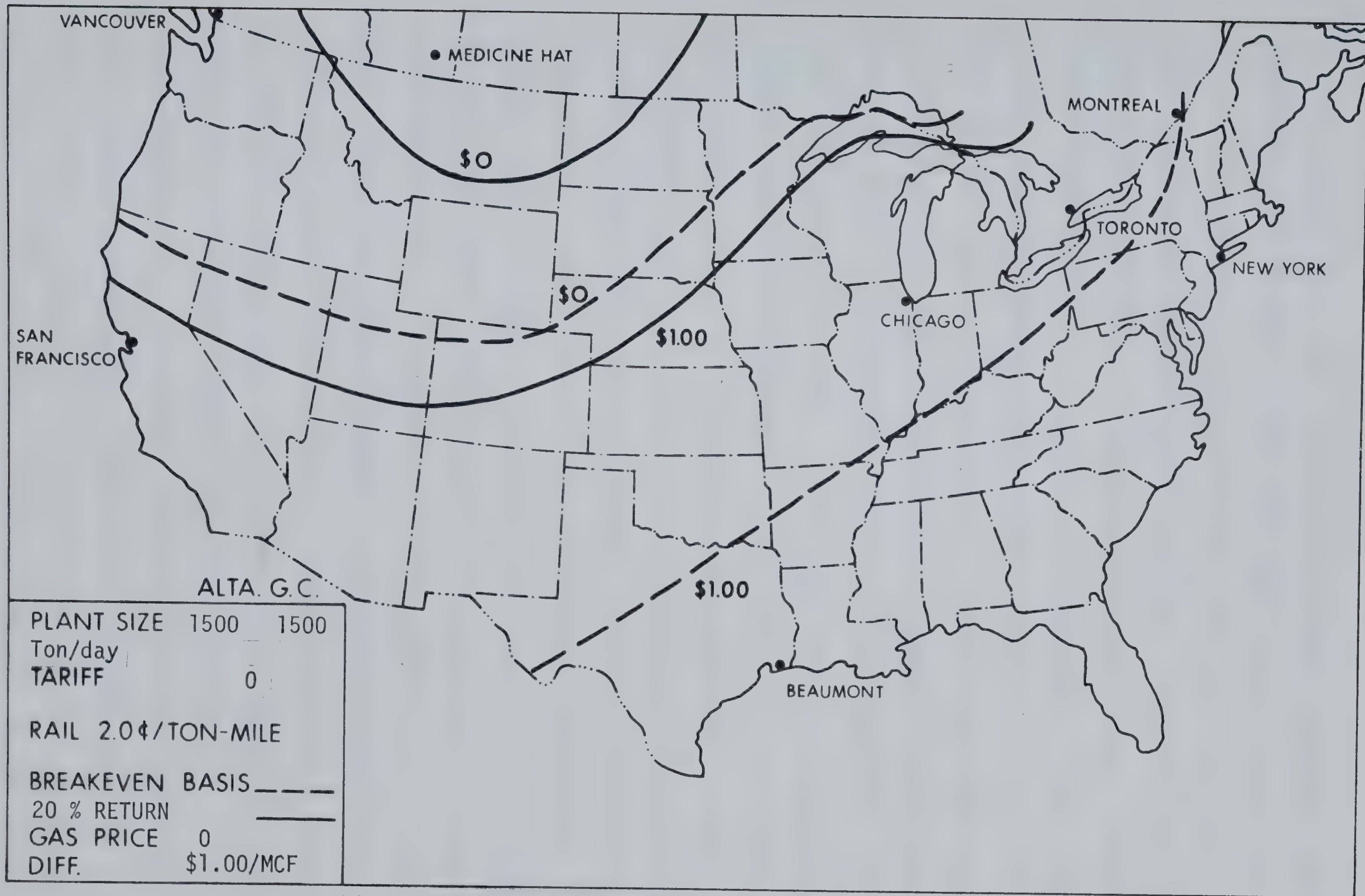

Figure 19. Effect of Breakeven vs. 20% Return Costs on Ammonia Market

Of course, competition for the American ammonia market may come from Middle East producers, since these countries have abundant supplies of low-cost natural gas. Production costs for a 1500 T/day Middle East ammonia plant are shown in Table 12. This plant size is typical of proposed plants in this area, and as yet no huge synthesis plant has been planned as in the case of methanol (24). Natural gas and fuel costs have been assumed negligible because gas is currently being flared. Taxes were also assumed to be zero because plants may be government-owned. Under these constraints, ammonia could be produced for 0.3¢/lb. Transportation costs from the Persian Gulf to the U.S. East Coast are about 0.8¢ - 1.1¢/lb (29), therefore Middle East ammonia would sell for a minimum of 1.1¢/lb in the U.S. This would be equivalent to Gulf Coast production costs using 40¢/Mcf natural gas. Higher gas prices would make Gulf Coast product noncompetitive. Similarly Alberta product could not compete with Middle East ammonia along the U.S. coast if feedstock costs were greater than 40¢/Mcf. However, access to Midwest U.S. would still be possible. It is likely, however, that a tariff would be imposed on imported ammonia if foreign competition forced U.S. producers to shut down operations. In this case, foreign producers would compete for the growth in ammonia consumption, rather than existing markets. Ammonia costs calculated for the Middle East also represent the minimum possible production costs. Natural gas costs may be a nominal value such as 25¢/Mcf to cover recovery costs. In addition, production from these countries would probably be destined for the relatively untapped markets in India and China. Because of the availability of low-cost natural gas and proximity to these countries, Middle East producers would easily

Table 12

Middle East Ammonia Production Costs

CAPACITY: 1050 MM lb/yr

FIXED CAPITAL $MM 48.8

WORKING CAPITAL $MM 1.7

		¢/lb		¢/lb
NATURAL GAS	@ $.00	0.000	@$.25/MCF	0.260
CATALYST		0.036		0.036
FUEL	@ $0.0	0.000	@$.25/MCF	0.175
ELECTRICITY		0.010		0.010
WATER		0.013		0.013
LABOR		0.026		0.026
MAINTENANCE		0.138		0.138
OVERHEAD		0.031		0.031
TAXES		0.000		0.000
SALES		0.034		0.043
	BREAKEVEN	0.286		0.730
DEPRECIATION		0.460		0.460
PROFIT		0.952		0.952
	PLANT GATE	1.70 ¢/lb		2.14 ¢/lb

capture these market areas. Profit margins in this market would also be much greater than in North America, because no other countries would be in a position to compete for these markets. For this reason, it seems unlikely that Middle East production will be marketed in North America, thus the Alberta position in U.S. markets is relatively secure.

The markets which have been analyzed reflect the case of commodity oversupply. This situation implies that consumers would buy from the cheapest supplier. U.S. natural gas shortages, however, may change this market structure. The effect of supply on ammonia production costs is shown in Table 13. For a production level of 50%, Gulf Coast breakeven operating costs are about 0.3¢/lb greater than when operating at full capacity, which would not significantly change market penetration. This conclusion is substantiated by Figure 20, which illustrates the markets for production levels of 100%, 75%, and 50% of capacity, for the zero and dollar gas price differentials. The geographic area in which Alberta-produced ammonia would be competitive is thus not appreciably affected by natural gas supply when based upon price comparisons alone. However, a uniformly distributed 50% gas shortage implies that U.S. ammonia production would be about 8 million tons short of demand. Alberta ammonia could be marketed wherever this shortfall occurred. Market is determined more by supply and demand than by cost comparisons in this case. The effect of gas supply will be discussed in detail in a later chapter.

Table 13

Effect of Natural Gas Supply on

Ammonia Production Costs

Gulf Coast

PLANT SIZE: 1500 T/DAY

PRODUCTION LEVEL	100%	75%	50%
RAW MATERIALS & UTILITIES	.496	.496	.496
LABOR	.026	.035	.052
MAINTENANCE	.115	.153	.230
OVERHEAD	.031	.041	.062
TAXES	.058	.077	.116
SALES	.040	.050	.068
BREAKEVEN PRICE	.77	.85	1.024
DEPRECIATION	.384	.512	.768
PROFIT	.828	1.100	1.656
F.O.B. PLANT	1.98 ¢/lb	2.46 ¢/lb	3.44 ¢/lb

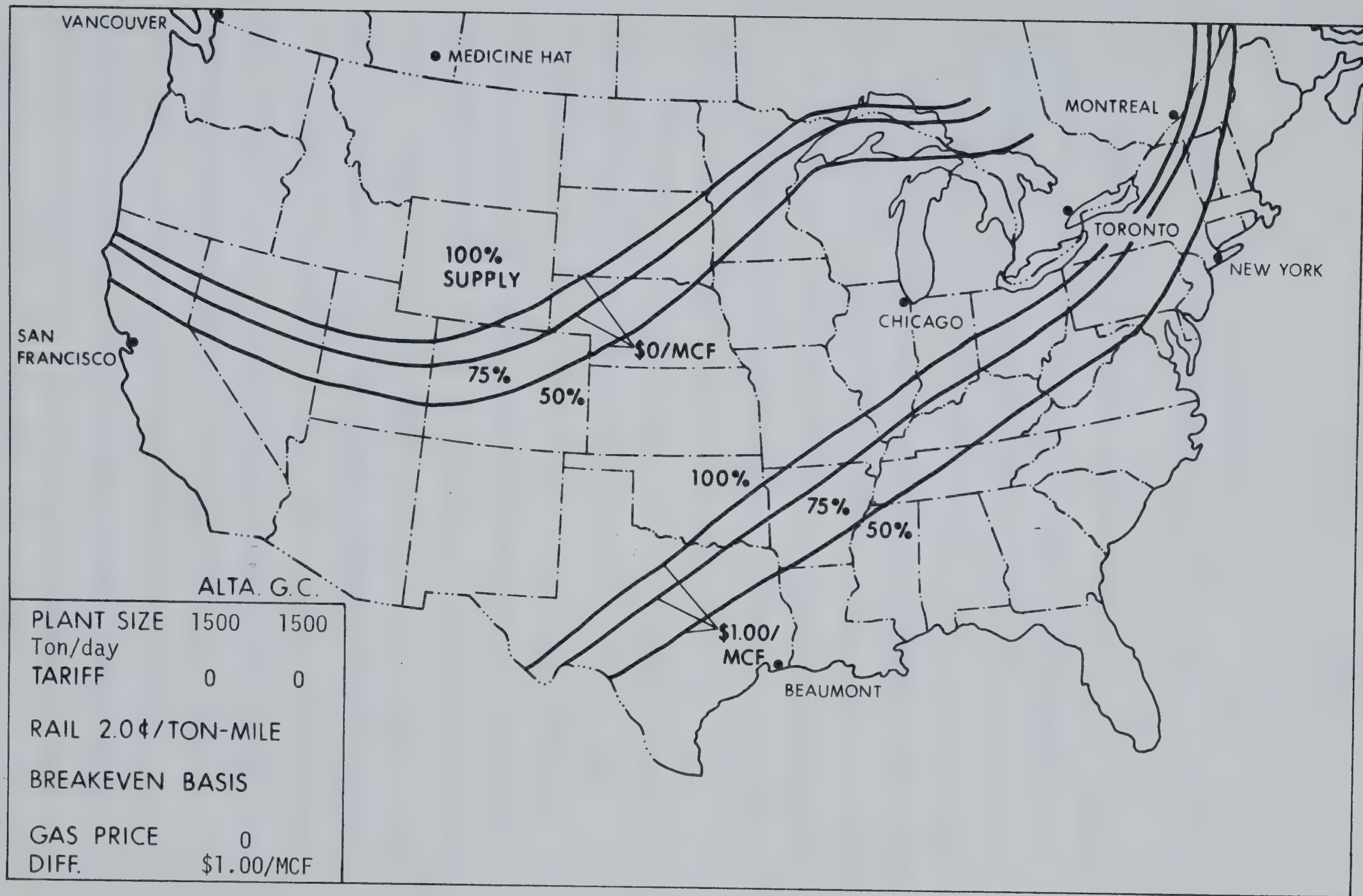

Figure 20. Effect of Natural Gas Supply on Ammonia Market

CHAPTER V

ETHYLENE MARKET ANALYSIS

Ethylene forms one of the major building blocks in the chemical industry and ethylene derivatives are used in the manufacture of thousands of goods, from antifreeze to records. The establishment of an ethylene complex in Alberta would provide the basis for major upgrading facilities and service industries. However, before plants can be built, the markets for the various products must be determined. This chapter will examine the market for Alberta-produced ethylene and its derivatives and the sensitivity of the market to changes in feedstock price, freight rates, and tariffs.

Ethylene is most economically made from ethane or propane, but naptha and refinery off-gases are also used as ethylene feed. The first Alberta ethylene plants will use ethane. About 70% of U.S. plants currently use either ethane or propane (30). For these reasons, Alberta and U.S. production costs were based upon the cost of ethane, although the use of naptha in U.S. plants may become increasingly important as gas prices rise and ethane availability declines.

The market for Alberta ethylene was determined using the model described previously. Alberta producers were compared to Gulf Coast producers on the basis of breakeven production costs. Breakeven costs refer to the plant gate price minus profit and depreciation and represent the minimum price at which a producer can sell his product. The price of ethylene in a market area equals production costs plus transportation charges plus tariffs. The producer which can market

his product in a potential market area for the cheapest cost is assumed to capture the entire market in the area.

The potential ethylene market is concentrated in eastern Canada and the United States. Figure 21 shows the ethylene capacity in North America in 1974 in millions of pounds per year (14, 15). Since most ethylene is converted to derivatives at the point of manufacture, the ethylene market would be essentially as shown in the figure. It is apparent that penetration must be made into the eastern market before a major ethylene complex could be built in Alberta. The potential market areas will now be determined.

The production costs for billion pound per year Alberta and Gulf Coast ethylene manufacturers (6) are shown in Table 14. An ethane price of 2.0¢/lb was used in calculating the production costs of both plants. A price of 2.0¢/lb equals the cost of ethane extracted from natural gas priced at 50¢ - 60¢/Mcf (31), which is the current price in the United States, and the expected price of gas in Alberta in 1975 (18). As shown in the table, a Gulf Coast producer's f.o.b. price for ethylene would be 0.5¢/lb less than an Alberta manufacturer's, but the breakeven cost for both plants would be about 3.5¢/lb. It should be remembered that although 50¢/Mcf was used in determining ethylene production costs, using $1.50/Mcf would not affect the market calculations because the difference between Alberta and Gulf Coast breakeven production costs would still be negligible.

Using 3.5¢/lb as the cost of ethylene production, the base case ethylene market line was determined, as illustrated in Figure 22. This line represents equal Gulf Coast and Alberta ethylene cost. In general, Alberta product is only marketable north of this line. In

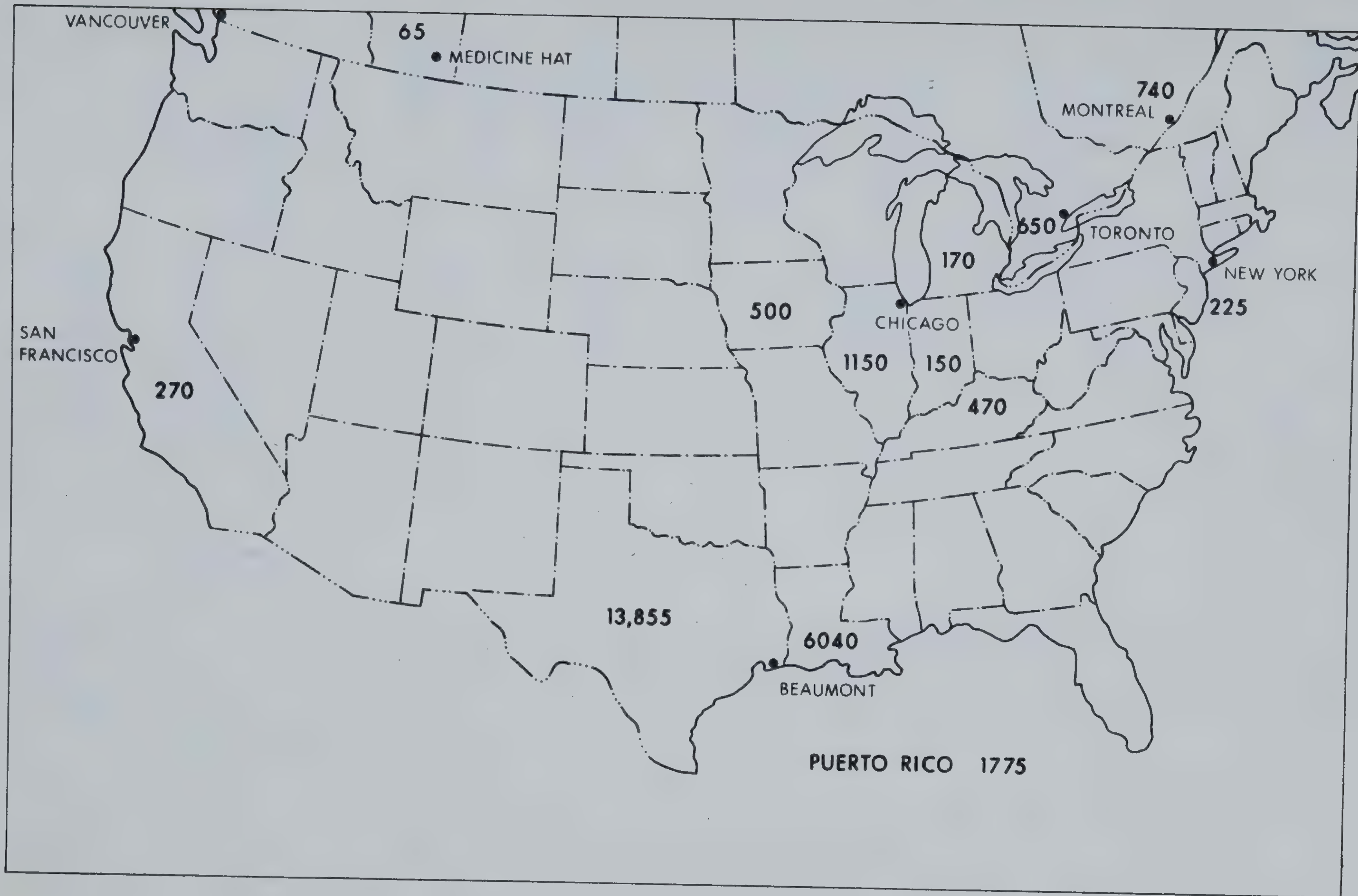

Figure 21. Ethylene Capacity (MM lb.)

Table 14

Ethylene Production Costs

		ALBERTA	GULF COAST
CAPACITY	MM LB/YR	1000	1000
FIXED CAPITAL	$MM	83.0	68.0
WORKING CAPITAL	$MM	11.9	11.0
		¢/lb	¢/lb
ETHANE	$.02/lb	2.49	2.49
CAUSTIC SODA	$.04/lb	.025	.025
FUEL	$.50/MCF	.340	.340
ELECTRICITY		.017	.017
PROCESS WATER		.001	.001
COOLING WATER		.145	.145
STEAM		.416	.500
LABOR		.059	.059
MAINTENANCE	3% FIXED	.248	.204
OVERHEAD		.070	.070
TAXES		.124	.102
DEPRECIATION		.830	.680
SALES	2%	.136	.126
PROFIT		1.900	1.580
		6.80	6.33

BY-PRODUCT CREDIT:		¢/lb
RESIDUE GAS	@50¢/MCF	.26
PYROLYSIS GASOLINE	@$.030/lb	.06
C_3 - C_4	@$.040/lb	.25

		ALBERTA	GULF COAST
BREAKEVEN PRICE	=	3.50 ¢/lb	3.50 ¢/lb
PLANT GATE PRICE	=	6.23 ¢/lb	5.76 ¢/lb

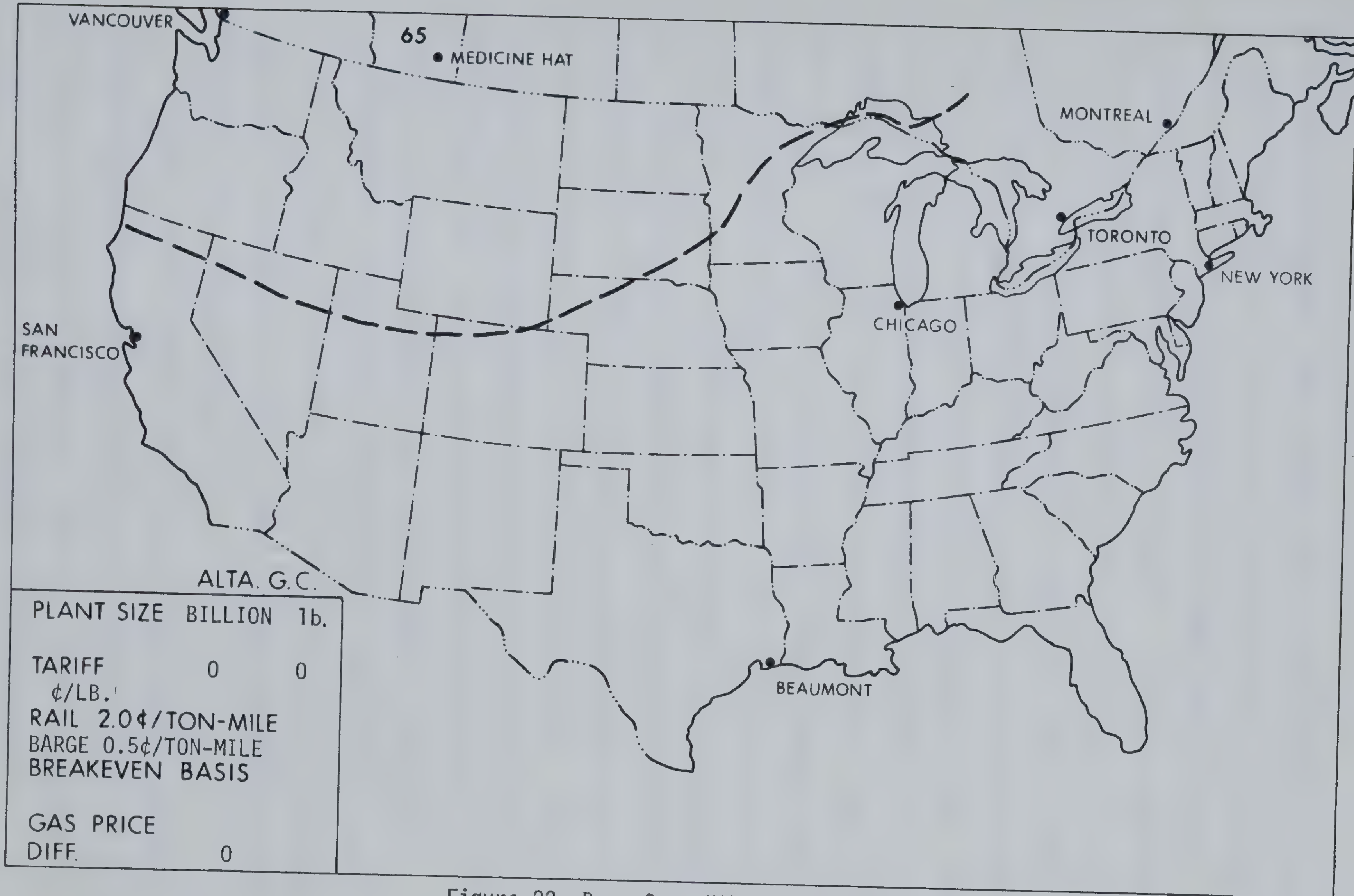

Figure 22. Base Case Ethylene Market

determining the market line, freight rates of 2¢/Ton-mile by rail and 0.5¢/Ton-mile by barge were assumed. This was done to be consistent with the ammonia and methanol analyses, although large volumes of ethylene are shipped by pipeline to consumers. As in the case of ammonia, no tariff is levied on ethylene imported into Canada or the U.S. (7, 8). As illustrated in Figure 22, the base case ethylene market would only encompass Western Canada plus a small fraction of Northwest U.S., an area which produced only 65 MM lbs of ethylene in 1974. However, although significant amounts of ethylene are transported by refrigerated tank car and barge, pipeline is the most common mode of transport. The base case calculations were therefore repeated considering an ethylene pipeline from Alberta to Sarnia, with connections to Illinois. Such a pipeline would enable ethylene to be transported for 0.6¢/Ton-mile (32). However, as shown in Figure 23, a pipeline would only expand the base case market to encompass southern Ontario, which has an ethylene capacity of about 0.6 billion pounds. The constraints of high transportation costs and no gas price advantage impose serious restrictions on the market for Alberta ethylene. It should also be noted, however, that ethylene demand is expected to increase at 10 - 15% per year, and may double by 1980 in North America (30). This means an additional 20 - 25 billion pounds of ethylene capacity will be required by 1980. Alberta production would be easily absorbed by this increased demand.

However, whether ethylene will be exported now appears uncertain. Dow originally applied for an export permit to ship 10 billion pounds of ethylene to Sarnia and then to U.S. markets (16). This project has been temporarily abandoned, although an ethylene complex

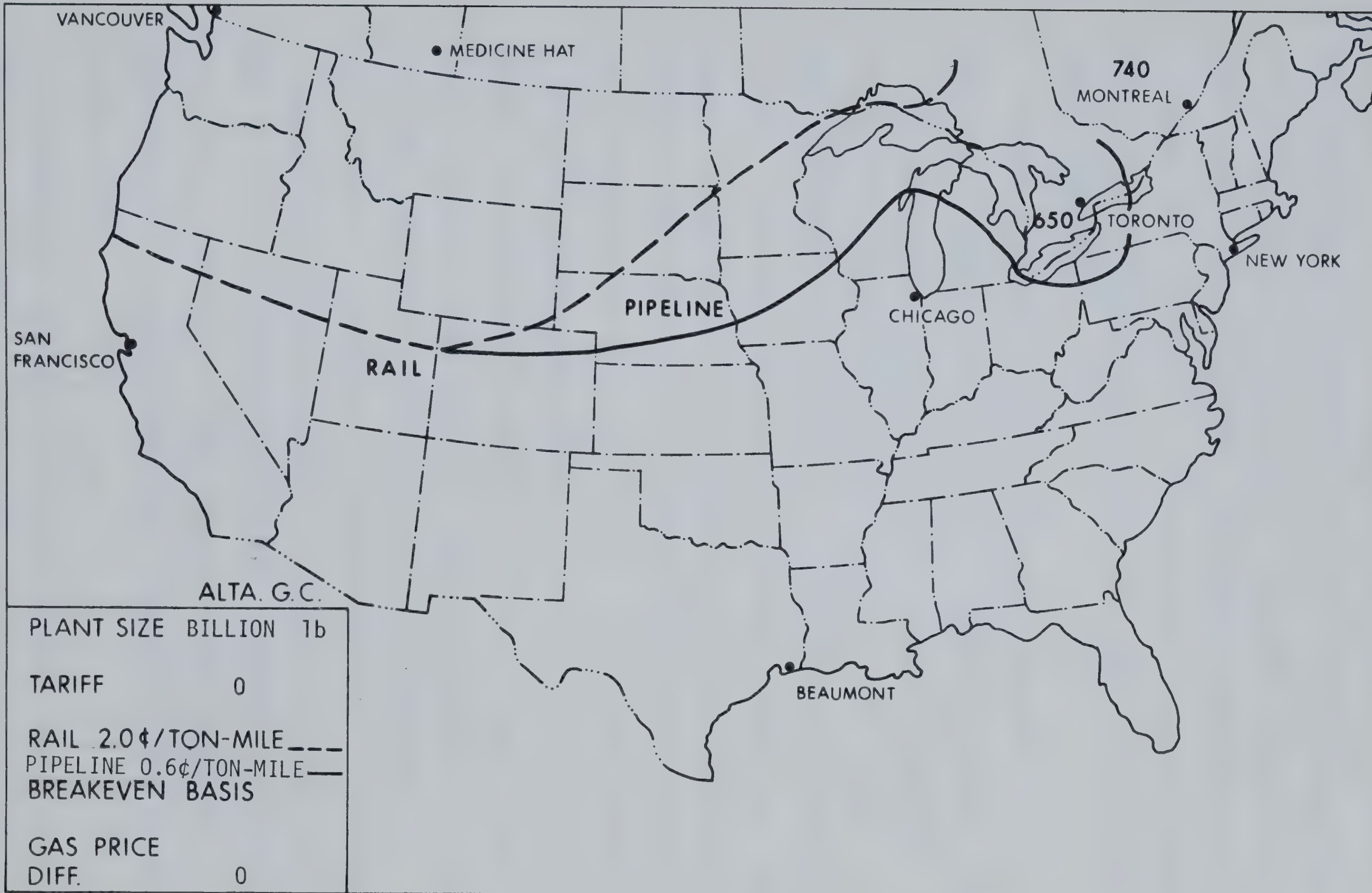

Figure 23. Effect of Ethylene Pipeline

will probably be built in Alberta. It is more likely that ethylene derivatives will be marketed in the U.S., therefore the markets for these products will be determined. The polyvinyl chloride market will be studied in detail, since it is representative of the many ethylene derivatives, and freight rates and tariffs for each derivative are approximately equal.

Polyvinyl chloride (PVC) is a white powder made from the polymerization of vinyl chloride (33). Vinyl chloride is a gaseous intermediate usually manufactured by the oxychlorination of ethylene. North America vinyl chloride and PVC capacity in 1974 (15,16) is given in MM lb/yr. in Figure 24. It is interesting to note that the majority of vinyl chloride is produced on the Gulf Coast, but is processed as a resin mainly in the Northeast U.S. This is because it is cheaper to barge liquified vinyl chloride than manufacture PVC in Texas and ship the finished product to east coast markets. Most PVC is used in the construction industry, as well as for plastic pipe, records, and siding, and the molding facilities for these various uses are located in the Northeast U.S. (33). An interesting correlation can be noted when comparing PVC capacity to population. As shown in Table 15, the majority of the U.S. population is concentrated in the Northeast and Great Lakes area. Therefore, it appears that there is a direct correlation between resin consumption and population. Hence, even though Alberta-produced PVC may not penetrate eastern markets, the population centres in western U.S. may be potential outlets.

The production costs (6) for Alberta and Gulf Coast vinyl chloride and PVC are listed in Tables 16 and 17. These costs are based

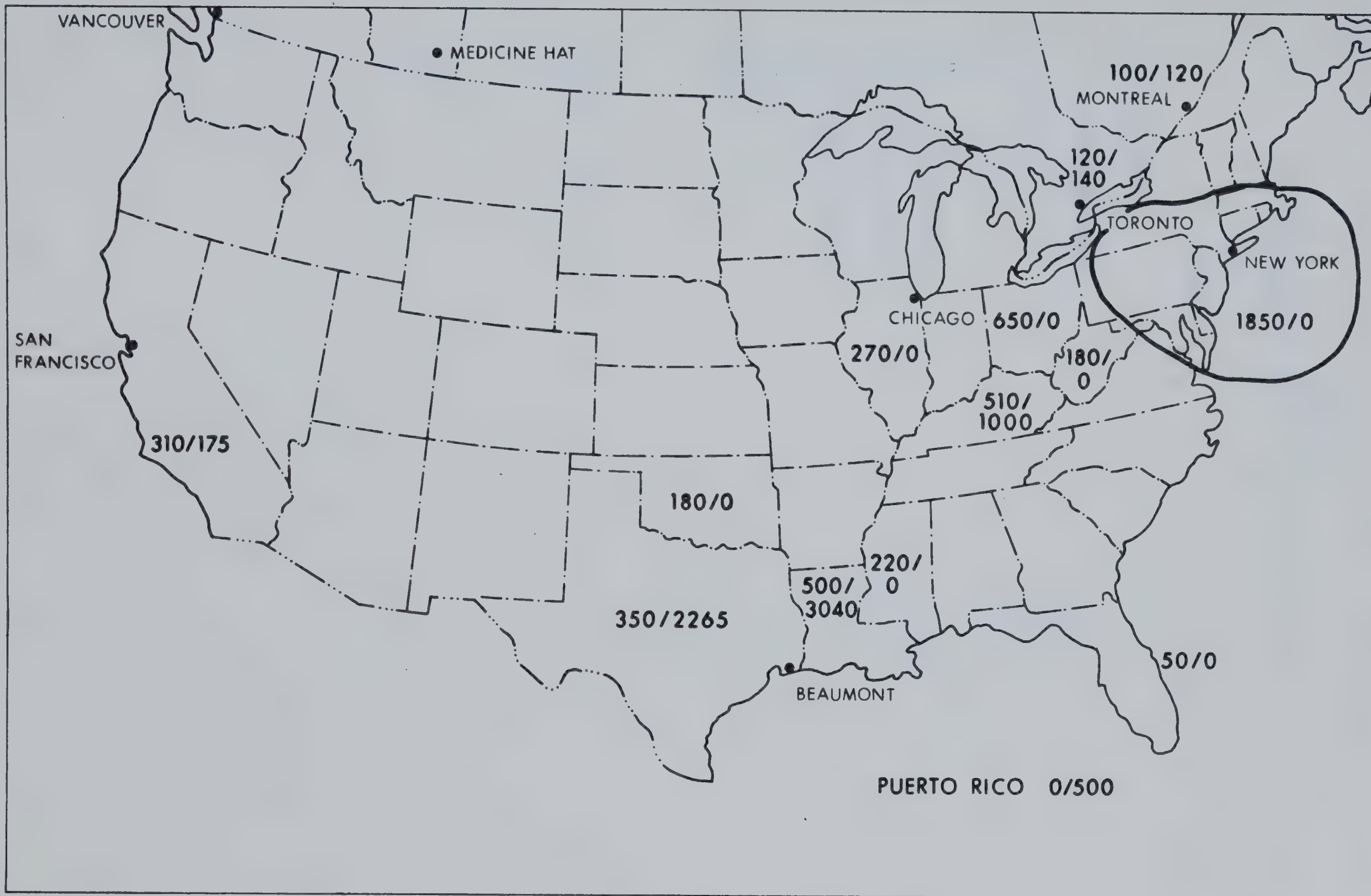

Figure 24. PVC/Vinyl Chloride Capacity (MM lb.)

Table 15

Population of the United States (1973)

AREA	POPULATION 1000'S
NEW ENGLAND	12,151
EAST-NORTH-CENTRAL	40,897
MID-ATLANTIC	37,528
SOUTH-ATLANTIC	32,459
EAST-SOUTH-CENTRAL	13,289
WEST-NORTH-CENTRAL	16,704
WEST-SOUTH-CENTRAL	20,257
MOUNTAIN	9,149
PACIFIC	27,417
	209,851

SOURCE: (34)

Table 16

Vinyl Chloride Production Costs

		ALBERTA		GULF COAST
CAPACITY	MM LB/YR	400		500
FIXED CAPITAL	$MM	22.7		21.4
WORKING CAPITAL	$MM	5.3		6.4
		¢/lb		¢/lb
ETHYLENE	@$.035/lb	1.68	@$.035/lb	1.68
CHLORINE	@$.035/lb	2.200		2.200
CATALYST		.115		.115
FUEL	$.50/MCF	.100		.100
ELECTRICITY		.100		.100
PROCESS WATER		.006		.006
COOLING WATER		.050		.050
STEAM		.196		.240
LABOR		.128		.128
MAINTENANCE	4% FIXED	.227		.170
OVERHEAD		.153		.153
TAXES		.078		.062
DEPRECIATION		.540		.432
SALES	5%	.370		.350
PROFIT		1.400		1.130
	PLANT GATE PRICE	7.34		6.92
	BREAKEVEN PRICE	5.40 ¢/lb		5.35 ¢/lb

Table 17

Polyvinyl Chloride (PVC) Production Costs

		ALBERTA		GULF COAST
CAPACITY		350		350
FIXED CAPITAL		19.9		16.6
WORKING CAPITAL	$MM	7.2		8.7
		¢/lb		¢/lb
VINYL CHLORIDE	@$.0540/lb	5.750	@$.0535/lb	5.700
CATALYST		.360		.360
FUEL	$.50/MCF	.025		.025
ELECTRICITY		.100		.100
PROCESS WATER		.030		.030
COOLING WATER		.050		.050
STEAM		.150		.180
LABOR		.401		.401
MAINTENANCE	4%	.228		.189
OVERHEAD		.481		.481
TAXES		.084		.070
DEPRECIATION		.575		.479
SALES	12%	1.320		1.310
PROFIT		1.580		1.470
	PLANT GATE PRICE	11.11		10.87
	BREAKEVEN PRICE	8.96 ¢/lb		8.92 ¢/lb
	BREAKEVEN PRICE BASED ON PLANT GATE VINYL CHLORIDE PRICE	11.35 ¢/lb		10.79 ¢/lb

upon the breakeven ethylene manufacturing costs shown in Table 14. PVC plant capacities were assumed to be 350 MM lb/yr for both Alberta and the Gulf Coast, as this capacity is typical of world scale plants. A 350 MM lb/yr PVC plant requires approximately 400 MM lb/yr of vinyl chloride feed (33), therefore 400 MM lb/yr was used as the Alberta vinyl chloride plant capacity. The Gulf Coast vinyl chloride plant size was assumed to be 500 MM lb/yr to show that plant size has marginal effect on production costs when comparing very large plants. As shown in Table 16, the breakeven cost of producing vinyl chloride would be about 5.4¢/lb for both the Alberta and Gulf Coast plants.

The PVC production costs tabulated were used to determine the line of equal cost, as illustrated in Figure 25. The line shown represents the cost of Gulf Coast and Alberta product delivered to the line, including production costs, transportation charges and tariffs. In general, Alberta product is marketable in all areas north of the boundary line. For purposes of price determination, freight rates of 2¢/Ton-mile by rail and 0.5¢/Ton-mile by barge or ocean tanker were assumed. For example, Alberta PVC delivered 500 miles into the U.S. would cost 11.2¢/lb, including 8.9¢/lb manufacturing costs, 0.5¢/lb transportation charges, and a tariff of 1.25¢/lb plus 6% ad valorem (8), or 1.8¢/lb. Gulf Coast product would cost 10.9¢/lb in the same area, including 2¢/lb freight charges and 8.9¢/lb production costs. Thus Gulf Coast product would capture the PVC market in this area. Based on plant gate vinyl chloride costs, Alberta PVC would be even less competitive with the Gulf Coast, as Table 17 shows.

The PVC manufacturers in North America, however, are located in eastern U.S. and along the Gulf Coast, therefore the existing base case market would be essentially zero. Two possibilities exist for

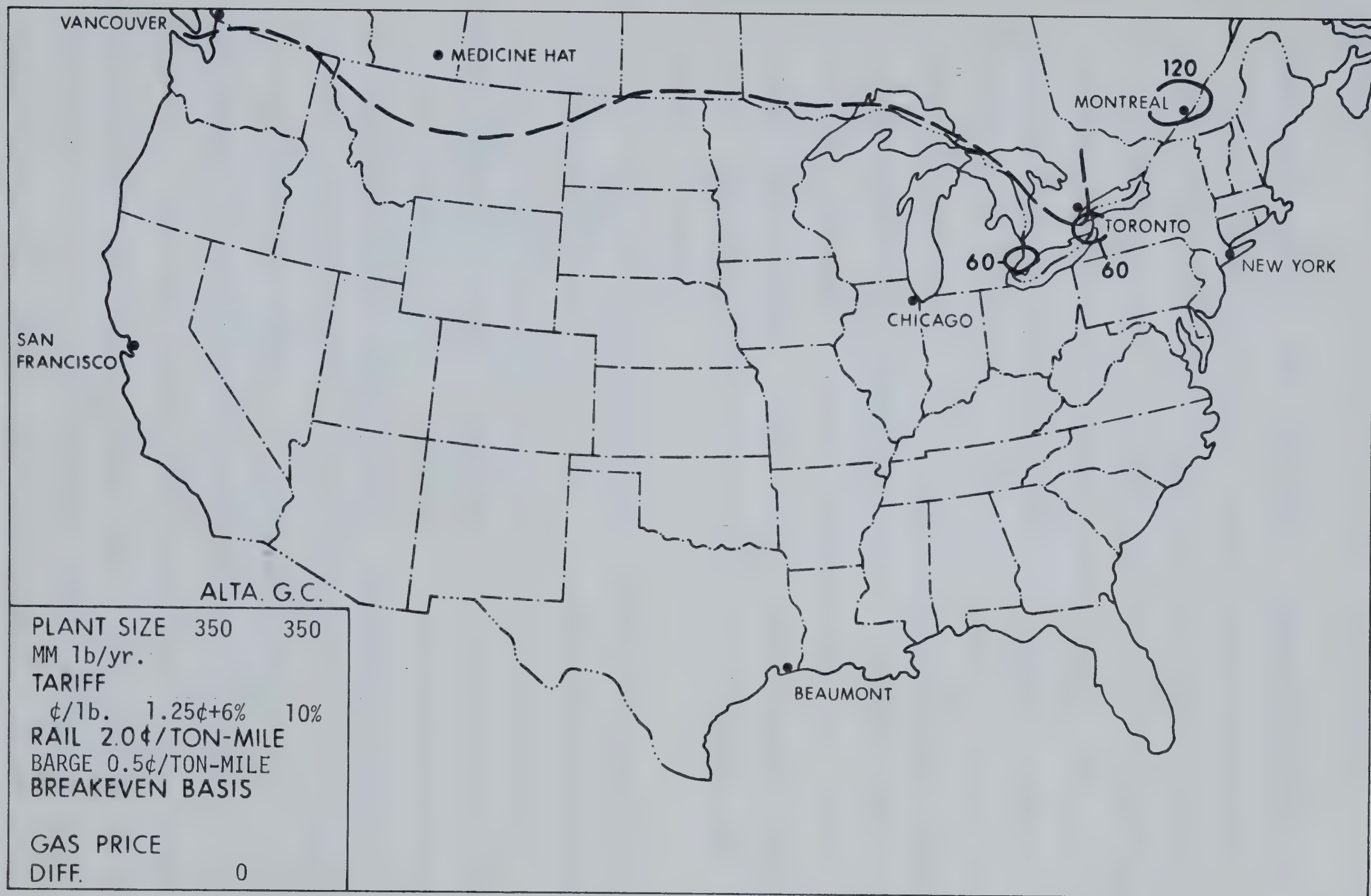

Figure 25. Polyvinyl Chloride Base Case Market

expanding the market. One is that Alberta producers could be given a feedstock price advantage or a reduction in tariffs or freight charges. The sensitivity of the market line to these various factors will be discussed shortly. The alternative would be that Alberta production will compete for the increased demand for PVC. PVC production reached 5100 MM lbs in the U.S. in 1972 (21). Demand is expected to increase at 11% annually for the next several years (33), so by 1980, consumption should double. This dramatic increase in demand implies that since uncertainty of feedstock supply will limit the number of new plants constructed in the U.S., foreign producers will have to meet the expected demand. In other words, a PVC undersupply situation will develop, and all of Alberta production could be absorbed into the U.S. market.

Of course, when PVC capacity exceeds demand, markets are determined mostly by PVC production costs. As mentioned previously, Alberta producers cannot penetrate the eastern markets using feedstock at prices comparable to the U.S. manufacturers, because of the high tariffs levied on imported products. The effect of feedstock price advantage to Alberta producers on the PVC market is illustrated in Figure 26. The market lines for feedstock price differentials of 0 to \$1.00/Mcf are represented in the figure. Gas price differentials of 0 to \$1.00/Mcf correspond to ethane price differentials of 0 to 2.8¢/lb (31). The difference in the cost of producing PVC, caused by a \$1.00 gas price differential, however, would be about 1.8¢/lb. This reduction in the impact of gas price increases as further processing occurs was shown in the introduction. Hence, as expected, gas price differential has a less significant effect on the

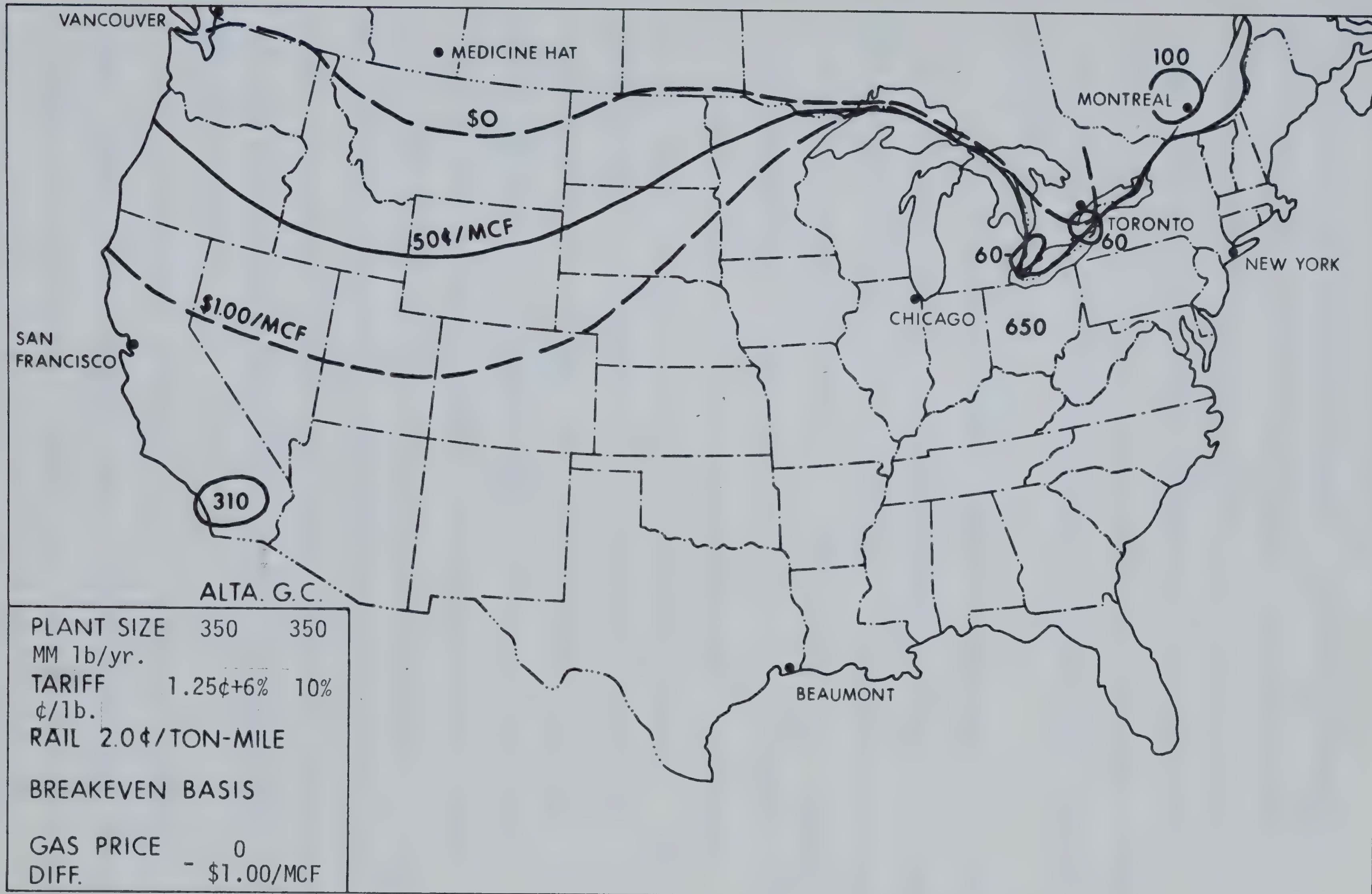

Figure 26. Effect of Gas Price Differential on PVC Market

PVC market than for methanol or ammonia. As shown in Figure 26, a \$1.00/Mcf gas price advantage would enable Alberta manufacturers to capture the eastern Canadian PVC market, but no penetration would be made into existing U.S. markets. Henceforth, to provide a prospective of gas price differential coupled with the various other factors affecting market penetration, two cases will be analyzed: the zero and dollar differentials.

The tariff levied on imported products has long been a major barrier to the establishment of a large petrochemical industry in Alberta. The current tariff structure was developed in the Kennedy Round Agreements and is under negotiation in the GATT hearings. As a result of these negotiations, a lessening of tariffs may occur. The effect of the removal of the tariff barrier on the PVC market is illustrated for the zero and dollar gas price differentials in Figure 27. Full tariff markets are designated by the solid lines and the markets excluding tariffs by the dotted lines. Removing the tariff would not expand the market for PVC appreciably if Alberta producers had no feedstock price advantage. However, a \$1.00 gas price differential would enable Alberta manufacturers to penetrate the eastern U.S. market. Current PVC capacity in this market area is over 2.5 billion pounds. Therefore, a combination of removal of tariffs plus substantial gas price advantage would enable a major PVC complex to be established in Alberta.

Another variable which affects market penetration is freight rates. Recall that for purposes of price determination, rail charges of 2¢/Ton-mile were assumed. However, unit train rates of 1¢/Ton-mile are typical, therefore the market lines were recalculated using

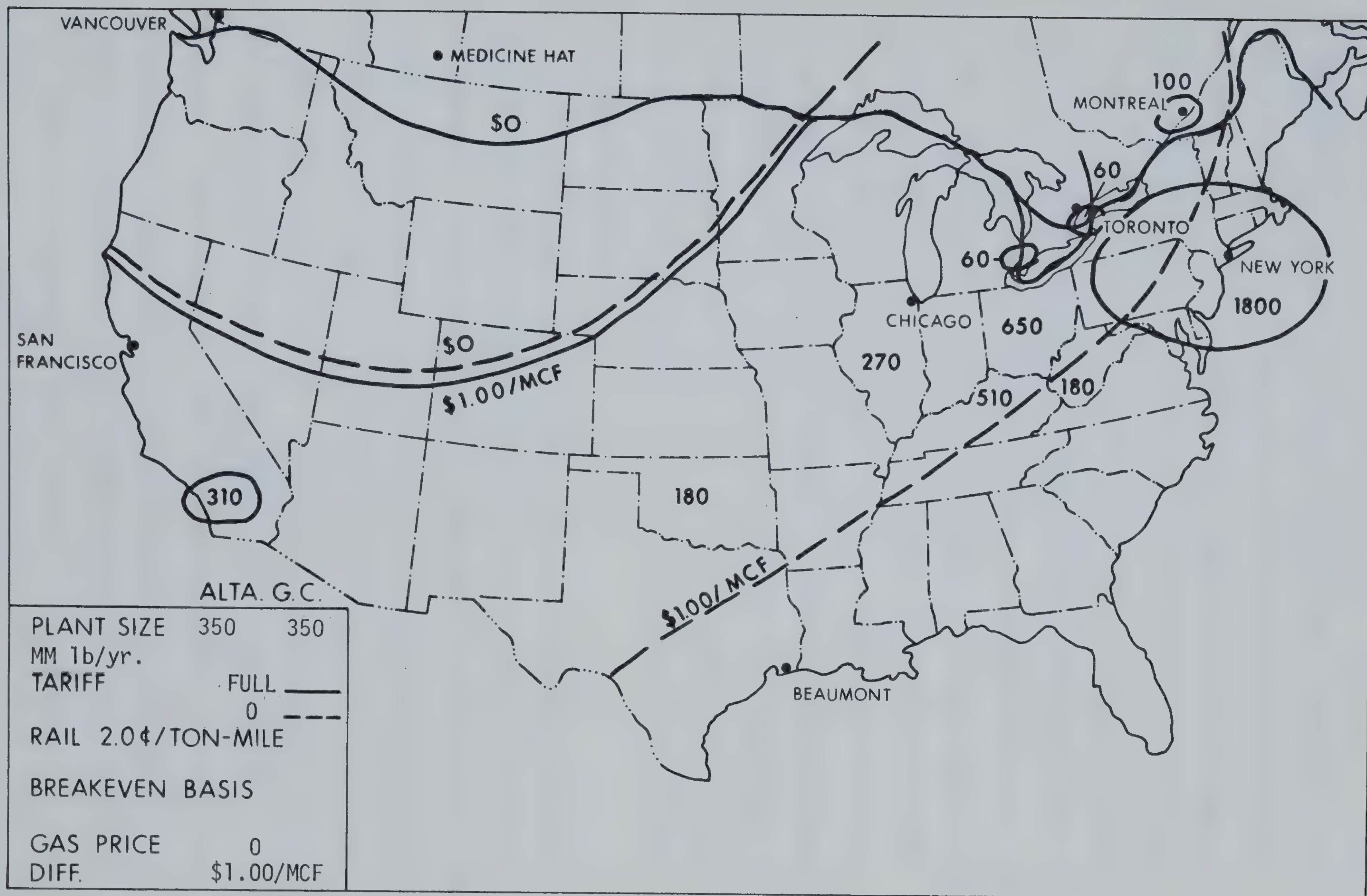

Figure 27. Effect of Tariffs on PVC Market

these rates. The market lines for the gas price differentials for the 1¢ and 2¢ freight charges are represented in Figure 28 by the dotted and solid lines, respectively. With no gas price advantage, Alberta product would be competitive with the Gulf Coast in the entire Canadian market, if the 1¢/Ton-mile rail charges were applicable. With a $1.00/Mcf advantage, the potential PVC market would only expand to encompass the California market, or about 33 MM lb/yr. Therefore, lobbying for lower freight rates would not assist Alberta producers as much as lower tariffs. Building a pipeline to transport vinyl chloride, which would be converted to PVC in eastern Canada, for example, would also not enhance the market for Alberta production appreciably. Pipeline charges would be about 0.7¢/Ton-mile(10), or only slightly less than unit train rates. The eastern U.S. market would still be inaccessible, if the tariff of 1.25¢/lb plus 6% ad valorem was imposed.

Two points should be realized concerning the market analysis. One is that market penetration studies reflect the cost of product oversupply, a situation which may not develop in North America. The studies did not determine exact markets, but rather the sensitivity of markets to changes in the variables which determine the prices of commodities in a market area. The case of gas undersupply, which will in turn cause shortages in some chemicals, will be discussed in later chapters. The other point which can be made is that if major petrochemical plants are built in Alberta, subsidiary companies may locate here which would refine the products produced. These companies would be assured of a relatively secure source of feed materials. In the case of PVC, for example, moulding and plastics pipe could be produced

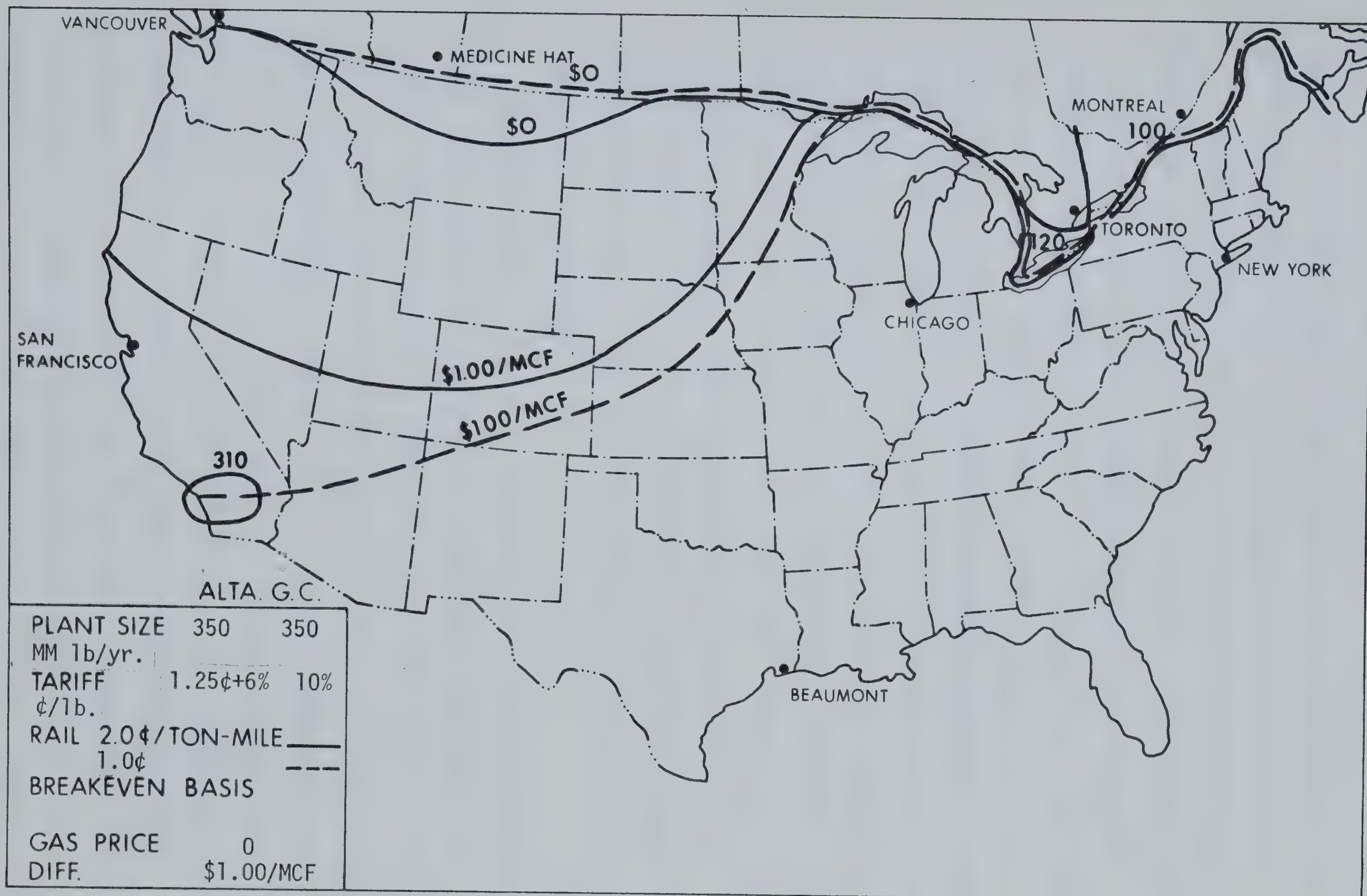

Figure 28. Effect of Rail Freight Rates on PVC Market

by such companies. These products may possibly be marketed in the large population centres in western Canada and the United States.

As mentioned previously, because tariffs on the various ethylene derivatives are approximately equal, and because freight rates were assumed to be equal for each commodity, the base case markets for each product are essentially the same. For example, the vinyl chloride market would be identical to that of PVC because the tariff on each would be 1.8¢/lb (8). The major difference between the various chemicals is in production costs and in the feedstock portion of these manufacturing costs. Hence, gas price differential will have a different effect on the market line for each chemical. Therefore, two cases only will be analyzed for each derivative: the base case market (zero-differential) and the one dollar differential. The production costs and uses for each derivative will also be presented. Ethylene oxide and polyethylene, two of the major ethylene derivatives, will be examined.

Ethylene oxide is manufactured by the direct oxidation of ethylene. About 60% of the ethylene oxide produced is converted into ethylene glycol to be used as antifreeze, but small amounts are also used in glycol ethers, diethylene glycols, and surface-active agents (30). The production costs (6) for 300 MM lb/yr Alberta and Gulf Coast plants, which is a typical world-scale plant size, are shown in Table 18. Using the breakeven production costs tabulated, the market lines for ethylene oxide for the zero and dollar gas price differentials were determined, as illustrated in Figure 29. These lines reflect transportation charges of 2¢/Ton-mile by rail and 0.5¢/Ton-mile by barge, and a tariff of 10% on Canadian imports (9),

Table 18

Ethylene Oxide Production Costs

		ALBERTA		GULF COAST
CAPACITY	MM LB/YR	300		300
FIXED CAPITAL	$MM	24.6		19.5
WORKING CAPITAL	$MM	5.2		5.0
		¢/lb		¢/lb
ETHYLENE	@$.0350/lb	3.65	@$.035/lb	3.65
UTILITIES AND OXYGEN		1.71		1.74
LABOR		.193		.193
MAINTENANCE	6% FIXED	.492		.390
OVERHEAD		.230		.230
TAXES		.116		.095
SALES	6%	.580		.540
DEPRECIATION		.830		.655
PROFIT		1.930		1.650
	PLANT GATE PRICE	9.73 ¢/lb		9.08 ¢/lb
	BREAKEVEN PRICE	6.97 ¢/lb		6.77 ¢/lb

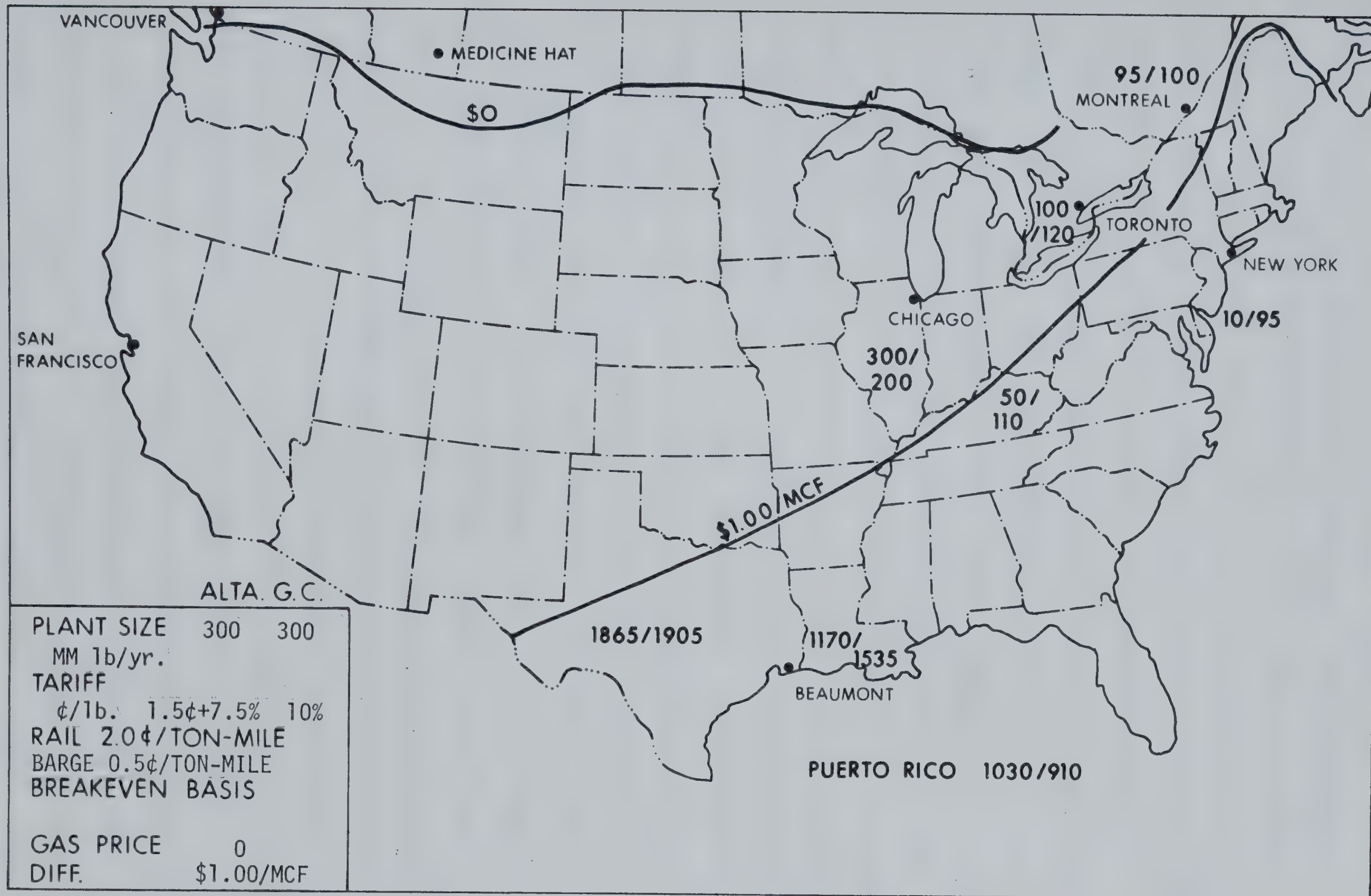

Figure 29. Ethylene Oxide/Glycol Base Case Market

1.5¢/lb plus 7% ad valorem on U.S. imports (8). The 1974 ethylene oxide and glycol plant capacities (15, 16) are also represented in Figure 29. As expected, the base case market for ethylene oxide is almost identical to the PVC market in terms of area. However, because feedstock forms a greater percentage of the manufacturing cost of ethylene oxide, the dollar price differential market is substantially larger than for PVC. Again, most ethylene oxide eventually is converted to antifreeze, and the northern states would consume the bulk of production, even though very little oxide is manufactured there.

Polyethylene is the remaining derivative which will be discussed. Ethylene is also manufactured into ethyl alcohol, ethylbenzene, plus various other chemicals, but polyethylene, ethylene oxide and vinyl chloride are the major derivatives. Polyethylene is manufactured by polymerizing ethylene and is used mainly in film and plastic sheet (35). Two forms of polyethylene are manufactured, low and high density, but the ratio of low density capacity to the latter is about 3 to 1 (14), therefore low density polyethylene will be examined.

The production costs for 500 MM lb/yr Alberta and Gulf Coast plants (6) are listed in Table 19. Production costs for an Alberta plant of 500 MM lb/yr capacity, which is a typical world-scale plant, would be 7.8¢/lb on a breakeven basis using 3.5¢/lb ethylene feed compared to 7.6¢/lb for the Gulf Coast plant of similar size. Using these production costs, the market analysis presented in the model description was applied to obtain the polyethylene base case and dollar differential market lines, as illustrated in Figure 30. Under the constraints of 2¢/Ton-mile rail freight charges and full tariff barriers, Alberta product would not be competitive in eastern Canada

Table 19

Low Density Polyethylene Production Costs

		ALBERTA		GULF COAST
CAPACITY	MM LB/YR	500		500
FIXED CAPITAL	$MM	91.4		76.7
WORKING CAPITAL	$MM	11.6		10.6
		¢/lb		¢/lb
ETHYLENE	@$.035/lb	3.63	@$.035/lb	3.63
CATALYST		.310		.31
ELECTRICITY		.545		.545
STEAM		.100		.120
COOLING WATER		.075		.075
LABOR		.220		.220
MAINTENANCE	4% FIXED	.731		.614
OVERHEAD		.264		.264
TAXES		.274		.232
SALES	12% SALES	1.650		1.510
DEPRECIATION		1.828		1.534
PROFIT		4.10		3.440
	F.O.B. PLANT	13.73		12.59
	BREAKEVEN	7.80		7.62

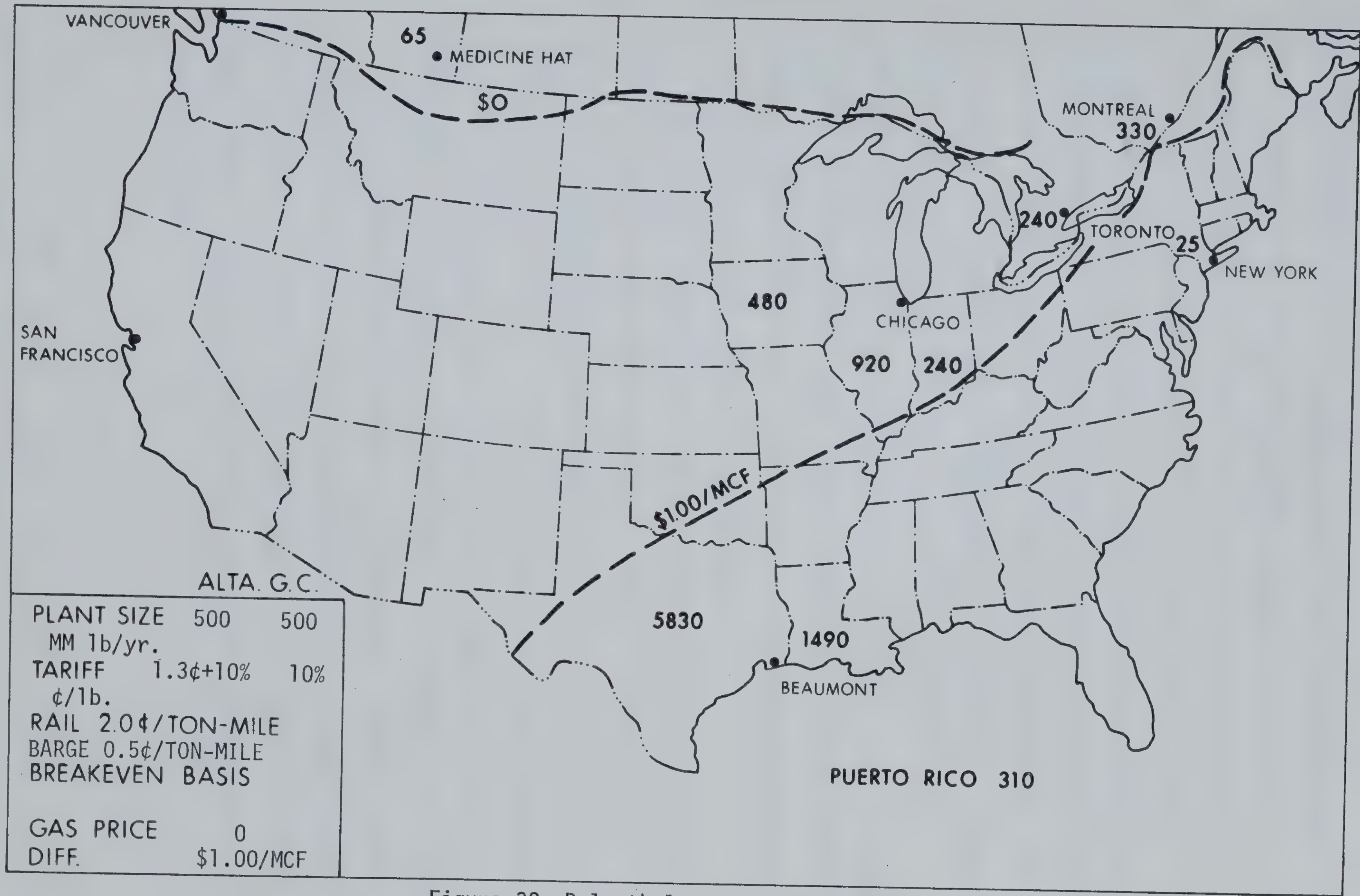

Figure 30. Polyethylene Base Case Market

or in any substantial U.S. markets, given no gas price advantage. With a dollar differential in gas price, however, the eastern Canadian market plus the Great Lakes area would be potential markets for Alberta polyethylene. As shown in the figure, current capacity in this area is about 2.3 billion pounds, thus a major polyethylene industry could be established in Alberta. Polyethylene consumption in the U.S. was about 5.4 billion pounds in 1972 (21) and is expected to increase at an annual rate of at least 10%, therefore demand should double by 1980 (35). An additional 600 MM lbs of polyethylene will also be required in Canada by 1980 if demand increases at the anticipated rate. Hence, unless significant changes in demand occur, production from the Alberta plants could be easily absorbed by the increase in North American consumption.

All of the previous market analysis shows that Alberta chemical plants require substantial concessions, either in the form of low tariffs or feedstock price advantages, to capture a large export market. Of course, this is true only in a competitive market situation, where prices and markets are dictated by the competitor's costs of production, plus freight rates, plus tariffs to potential market areas.

When demand exceeds capacity at a given price, however, a commodity shortage results, and prices are determined more by the demand for a particular commodity than by the costs of producing it. Some simple economic theory might be helpful in clarifying the concepts of supply and demand.

CHAPTER VI

NATURAL GAS SUPPLY MODEL

According to classical economic theory, supply and price are always at or moving toward equilibrium in the long term (36). If price exceeds the equilibrium value, supply will exceed the amount demanded, and price will consequently drop to encourage increased consumption. Similarly, if the price of a commodity is less than the equilibrium value, demand will exceed supply, and the competitive market forces would push the price up. When either situation exists in the long term, there is generally a shift in the supply or demand curve, which establishes a new market price.

The market analyses of the previous chapters were restricted to the case of commodity oversupply. In this instance, productive capacity exceeds consumption and prices are determined primarily by production costs. The results obtained represented the lowest prices for chemical commodities in a competitive market.

Suppose on a short term basis, however, that the supply of a commodity is fixed or can only be changed very slowly, i.e., it is not possible to shift the supply curve by expansion of capital facilities. When the potential demand exceeds the supply level, a commodity shortage results. Price is then dictated more by market forces than the costs of producing the commodity.

A commodity shortage may result from a variety of factors including excessive demand induced by low prices, poor foresight on the part of the producer, or a shortage of feedstock materials. The following chapters examine the case of undersupply of one such feedstock, natural

gas, and its effect on chemical prices. This is not an unreasonable situation to analyze as it has been widely predicted that there will be a shortfall between potential demand and supply of natural gas in North America over the next decade. The analysis will be directly applied to ammonia and methanol, the prices of which are strongly dependent upon natural gas price and supply. The questions to be answered are: given a shortfall in feedstock supply, what is the maximum price that a producer would pay for assured gas supply and what would be the resulting price of the chemical produced?

This analysis will not predict the exact price of a commodity since that depends mostly on the consumer. However, there is a maximum value which a producer must sell his product at under these conditions to recover his capital investment. It is this minimum price which can be determined. The ammonia industry will be used hereafter in describing the model.

In a natural gas shortage situation, natural gas demand can be brought into balance with supply by either allowing free bidding for natural gas supplies or by a gas rationing system. In the former case, producers bid for a gas block, with usually the large, efficient and newer plants having a distinct competitive edge over smaller, less efficient plants due to economies of scale. However, because these large plants are relatively new, they require a 20% investment return to be economically viable. An older plant, though smaller, has been operating long enough to recover the initial capital investment and can operate with a much smaller profit margin. Because the operating curves for both producers are essentially parallel, there is no way that a large producer can cling to a 20% return and out bid a smaller producer

for natural gas supplies. A smaller producer will shut down only if he is forced to operate below his breakeven operating cost, which can only be achieved by putting restraints on the bidding system. Determination of gas prices based on a free bidding system was therefore abandoned.

The alternative to a free bidding system is an equal sharing of shortages in natural gas supply. That is, if a 5% curtailment was imposed on the entire ammonia industry, the intake of natural gas to each plant would be 95% of its requirement. Since each plant would produce less, unit costs of production would rise. The cost of ammonia at the existing gas prices will be determined using the "down-time" analysis discussed in the market studies.

CONSTRUCTION ANALYSIS

All of the foregoing analysis assumes that the market price for ammonia will be approximately equal to the f.o.b. plant gate price of the largest plant at a given gas supply level. Obviously this need not be true in practice since market demand dictates the commodity price. Many factors influence the demand for industrial chemicals. Condensing all of these factors into a demand versus price relationship is extremely difficult. When potential producers were considering building plants in the sixties and early seventies, they estimated the demand for these commodities at a given market price and sized their plants accordingly. It was hypothesized that the decision to build or not to build a plant was contingent upon the producer receiving a minimum of 20% return on investment capital at the commodity price predicted. In effect, these producers estimated a commodity price which was greater than their costs of production plus a 20% return. The actual market

price that resulted after the plant was constructed simply determined whether the firm received a rate of return above or below the assumed 20%.

The actual market that a commodity supported during a specific year and the commodity price during that period can be obtained from historical price-production data. It was postulated that historical data reflect the production costs plus investment return of the most efficient (and usually largest) plant built in any specific year. A plant construction model was developed to simulate the historical price-production data. The underlying assumption was that a plant would be constructed only if the production costs including 20% return of that plant were less than or equal to the production costs of the largest plant in existence at that time.

The plant construction model, therefore, estimates a plant size based on the production costs of the most recently built plant, assuming 100% feedstock availability. The equal sharing system determines what ammonia price will result for specific gas shortages. A comparison of the price-production data generated by each model is thus a comparison of two different feedstock situations: the historical trend of 100% gas availability and decreasing commodity prices due to the construction of large, efficient plants, and the future trend of gas curtailments and rising commodity prices.

Historical price-production data, obtained from the Chemical Economics Handbook (10) for the years 1950 to 1970, were discounted to 1977 dollars to establish a common base, since the construction costs approximate 1977 operating expenses. Prices were discounted at 4% since the Nelson construction index increased by this amount from 1950

to 1969 (37). Future price trends, based on production costs, could then be compared to historical prices which were assumed to be influenced by consumer demand.

In the model, commodity price is assumed to equal the production costs of the largest plant, as shown in the market studies. Average gas prices at points of consumption (38), shown in Table 20, were used to calculate feedstock costs. One other criteria is required before production costs can be predicted and that is plant size. Two methods can be employed to estimate plant size. One method used plant construction dates to predict production for a specific year. For example, if 1950 production was a billion pounds in 1950 and a 500 MM lb/yr plant was built in 1951, then production in 1951 was assumed to be 1.5 billion pounds. Ammonia price would equal the production costs of the 500 MM lb/yr plant, if it was the largest operating in that year. The other method of predicting plant size is to assume that new plants would be equal in capacity to market growth. New plants would be built, however, only if production costs for the plant were less than existing older plants. Market growth is estimated by assuming an annual growth rate (13% for ammonia) and using actual 1950 production as the reference point. For example, assuming a 13% demand increase, ammonia market growth between 1950 and 1951 would be 130 million pounds. If the criteria for plant construction was satisfied, the new plant would have a 130 MM lb/yr capacity and ammonia price would equal the production costs of this plant. This model will henceforth be designated as the plant construction model.

Table 20

Natural Gas Prices in the U.S.(38)

AVERAGE VALUE AT POINTS OF CONSUMPTION ¢/MCF

YEAR	WELLHEAD	SALES
1950	6.5	26.6
1	7.3	29.8
2	7.8	33.2
3	9.2	35.5
4	10.1	38.1
1955	10.4	40.0
6	10.8	41.5
7	11.3	43.1
8	11.9	46.2
9	12.9	47.7
1960	14.0	50.0
1	15.1	51.0
2	15.5	51.4
3	15.8	51.2
4	15.4	51.9
1965	15.6	52.2
6	15.7	52.3
7	16.0	52.0
8	16.4	50.4
9	16.7	51.5
1970	17.1	53.6
1	17.5	----

CHAPTER VII

AMMONIA SUPPLY ANALYSIS

The supply of synthetic ammonia has increased dramatically over the last few decades, to almost ten times its 1950 level (21). This dramatic growth rate has resulted in several interesting patterns of ammonia production and prices, as illustrated in Table 21. Although discounted prices (1977 dollars) declined, actual ammonia price generally increased up to 1968, at which time prices dropped substantially. This decrease was caused by a weakening in ammonia demand and subsequent oversupply situation.

Rapidly increasing demand also prompted the construction of large, efficient plants. Previous to 1965, plants were usually built with less than 200 MTon/yr capacities, whereas capacities exceeded 500 MTon/yr by the end of the decade(10). The difference between plant sizes implies that production costs of ammonia plants are different. Any change in the variables which comprise the cost of production would be felt in varying degrees by different plants. As an example, the cost of labor to a 500 MTon/yr ammonia producer is about 1/10 the cost to a 50 MTon/yr plant. Hence, a doubling of labor costs affect small producers more seriously than large producers. Similarly, large plants can afford higher gas prices. This chapter determines the effect of natural gas shortage on ammonia prices using the supply models of the previous chapter.

The plant construction model was applied to the ammonia industry to produce the results shown in Table 22. To briefly restate the

Table 21

Historical Ammonia Price-Production Data

YEAR	PRODUCTION MM LB	PRICE ¢/LB	DISCOUNTED PRICE ¢/LB
1950	3076	3.75	10.81
1955	6426	4.25	10.07
1960	9546	4.40	8.57
1965	17576	4.60	7.36
1967	23740	4.60	6.81
1968	24600	3.50	4.98

SOURCE: CHEMICAL ECONOMICS HANDBOOK (10)

Table 22

AMMONIA PRICE PRODUCTION RESULTS FOR A PLANT

CONSTRUCTION ANALYSIS BASED ON A 13% ANNUAL PRODUCTION INCREASE

PRODUCTION MM Lb/yr.	AMMONIA PRICE ¢/LB	DISCOUNTED PRICE (1977) ¢/LB
3076	2.77	7.98
5667	2.51	5.96
10440	2.30	4.48
19240	2.04	3.27
24560	1.94	2.87

analysis used, plant size was assumed equal to market growth, which was 13% annually for the period 1950 to 1967 (10). New plants were assumed to be built only if production costs were less than existing plants. Ammonia price was discounted at 4% to 1977 dollars and plotted against production to obtain the plant construction curve shown in Figure 31. Historical data from Table 21 are also plotted in the figure. As illustrated, the construction model predicted much lower ammonia prices than historical values. There are two reasons for this. One is that historical prices are list prices and include distribution and storage charges. In 1968 for example, the plant gate price on the Gulf Coast was \$40/Ton, or 2¢/lb, less than the list price(10). Since calculated prices approximate Gulf Coast plant gate prices, historical data were replotted, subtracting 2¢/lb for delivery charges (1968), to obtain the remaining curve of Figure 31. The historical data minus delivery charges parallel those calculated by the plant construction model. The other reason why historical prices are much higher than predicted values is that plant sizes of 5000 T/day were estimated by the construction model. The largest plant in existence, however, has a capacity of about 1500 T/day. The assumption that plant size would equal market growth thus produced giant plants.

To solve this problem, two options were available. One was to set a maximum plant size of 1500 T/day and repeat the plant construction calculations. The results of this analysis are listed in Table 23, from which the construction curve of Figure 32 was obtained. Historical data are also plotted in the figure. This approach produced better approximation of historical prices, although the difference

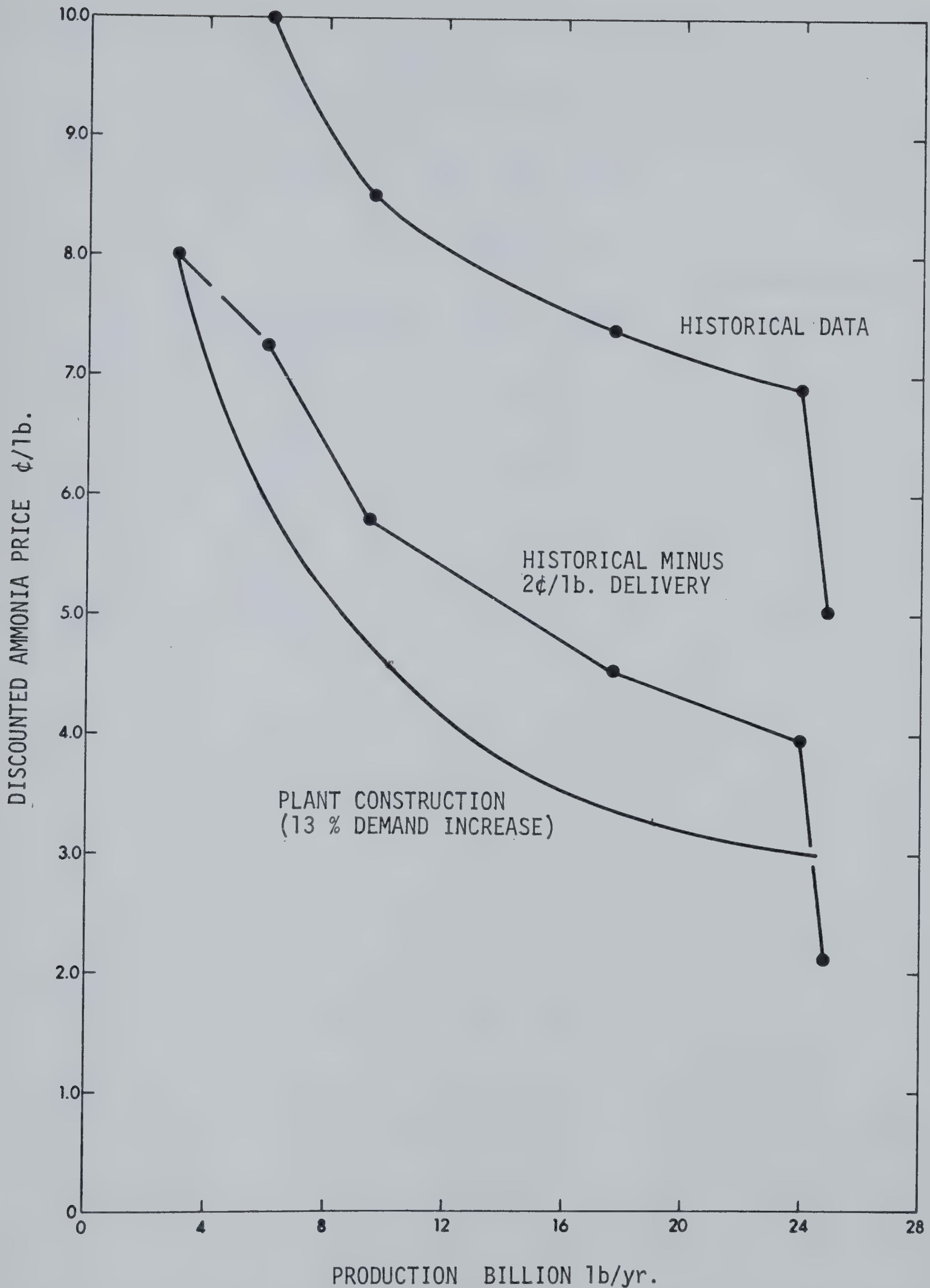

Figure 31. Historical Ammonia Price-Production Data and Plant Construction Results Calculated Using 13% Annual Production Increase

Table 23

Plant Construction Results

Maximum Plant Size 1500 TON/Day

YEAR	PRODUCTION MM LB/YR	AMMONIA PRICE ¢/LB (F.O.B. PLANT)	DISCOUNTED PRICE ¢/LB
1950	3076	2.77	7.97
1954	5366	2.18	5.38
1960	9546	2.39	4.65
1963	13266	2.41	4.16
1965	17576	2.43	3.90
1967	23600	2.42	3.60

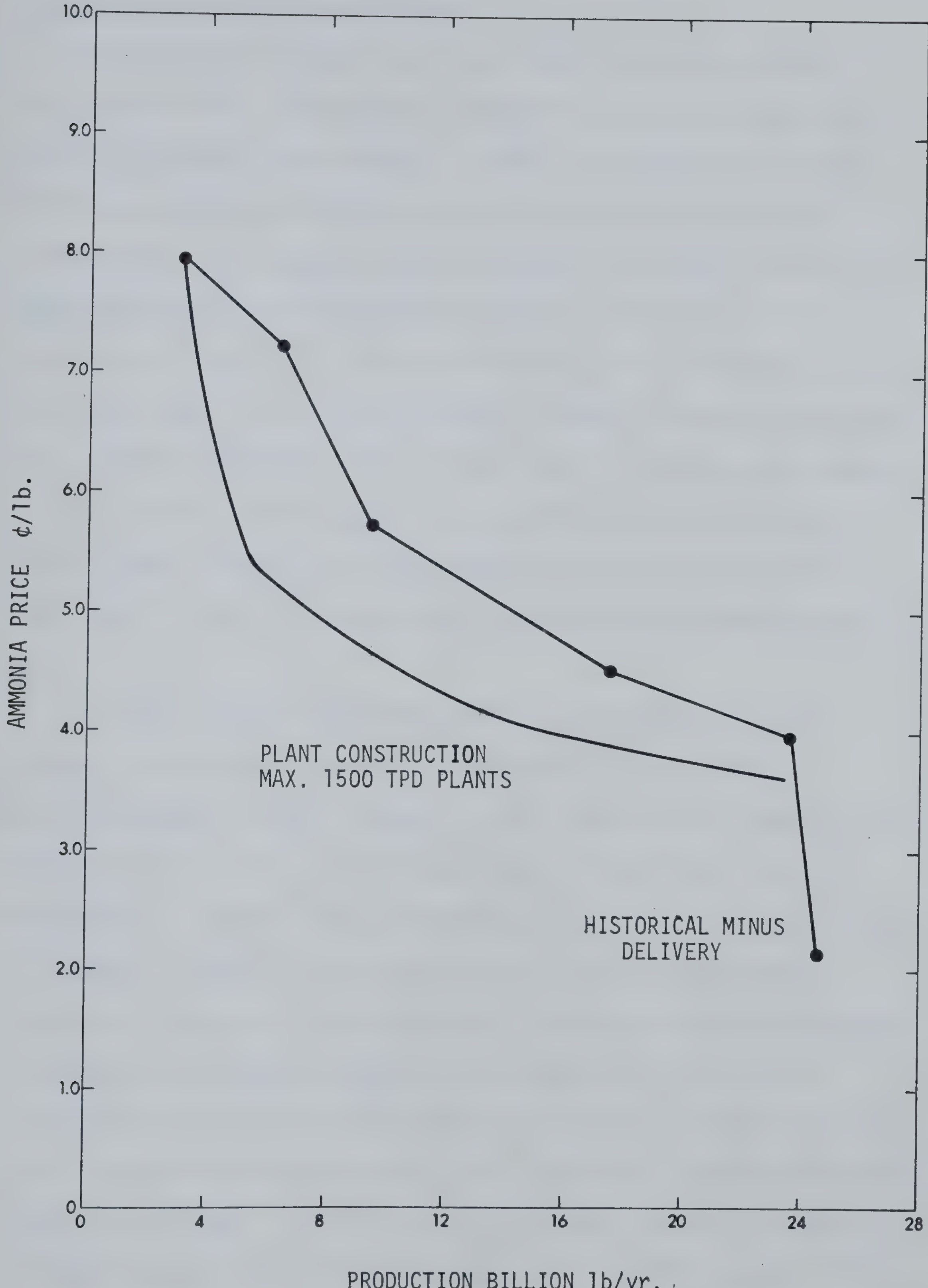

Figure 32. Historical Ammonia Price-Production Data and Results of Plant Construction Analysis Using Maximum 1500 TPD Plant Sizes

between prices is still significant.

An alternative approach was to use actual plant sizes in the construction model. The largest plant built in a specific year was assumed to dictate ammonia price. In 1961, for example, the largest plant had a capacity of 240 MM lb/yr and could produce ammonia for 3.7¢/lb (10). The results of such an analysis are listed in Table 24. Discounted price was plotted against production to obtain the construction curve of Figure 33. This curve exhibits good correlation with the historical curve, but historical prices are again higher than predicted for a specific production level, probably due to buoyant market demand. In 1968, however, a severe glut hit the ammonia industry when grain prices dropped, and this was compounded by the construction of many large ammonia plants. The oversupply situation caused ammonia prices to sag.

The equal sharing concept of natural gas shortages was then examined. Under such a system, gas shortages would be evenly distributed among various consumers. A 20% shortage, for example, would imply that all ammonia producers would obtain 80% of their feedstock requirements. Because plants are producing less, but all fixed charges are constant, production costs would rise. The shut-down analysis described in the market studies was used to determine chemical costs as a function of gas supply. Ammonia price was plotted against gas shortage for the equal sharing system in Figure 34. The equal sharing costs are based on production costs of a 1500 Ton/day ammonia plant using 50¢/Mcf natural gas. The 1975 field value of U.S. natural gas was set at 50¢/Mcf by the Federal Power Commission (4), so this was used. Note that even for a 50% gas curtailment, the resulting ammonia price would

be less than 4.0¢/lb, based solely on costs of production. The historical price of ammonia did not dip below 4¢/lb until 1968, as was shown by Figure 32, so obviously market forces significantly influence commodity prices. Of course, a gas price of 50¢/Mcf may be unrealistic in future because of the rapid depletion of U.S. gas reserves. In the next chapter, gas prices that ammonia producers can afford based on the demand of ammonia are estimated.

Table 24

Plant Construction Results Using Actual Construction Dates

YEAR	PRODUCTION MM LB	PLANT SIZE MM LB/YR	AMMONIA PRICE ¢/LB	DISCOUNTED PRICE ¢/LB
1953	4580	380	2.93	7.52
1956	6750	220	3.67	8.36
1961	10410	240	3.73	6.98
1963	13380	420	3.12	5.40
1965	17580	960	2.48	3.96
1967	23740	1020	2.43	3.60
1969	26000	1020	2.42	3.32

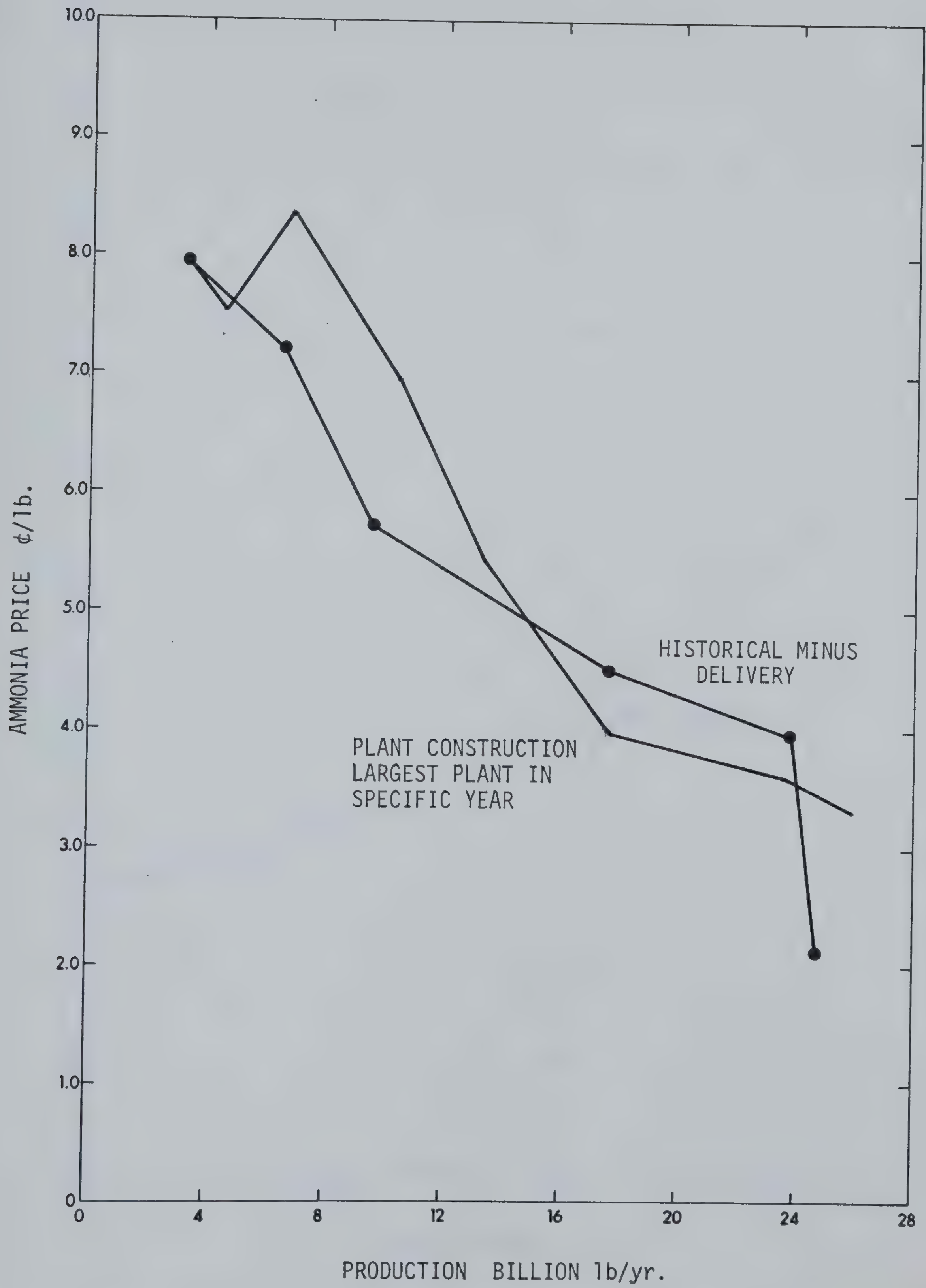

Figure 33. Historical Ammonia Price-Production Data and Results of Plant Construction Analysis Calculated Using Actual Plant Construction Dates

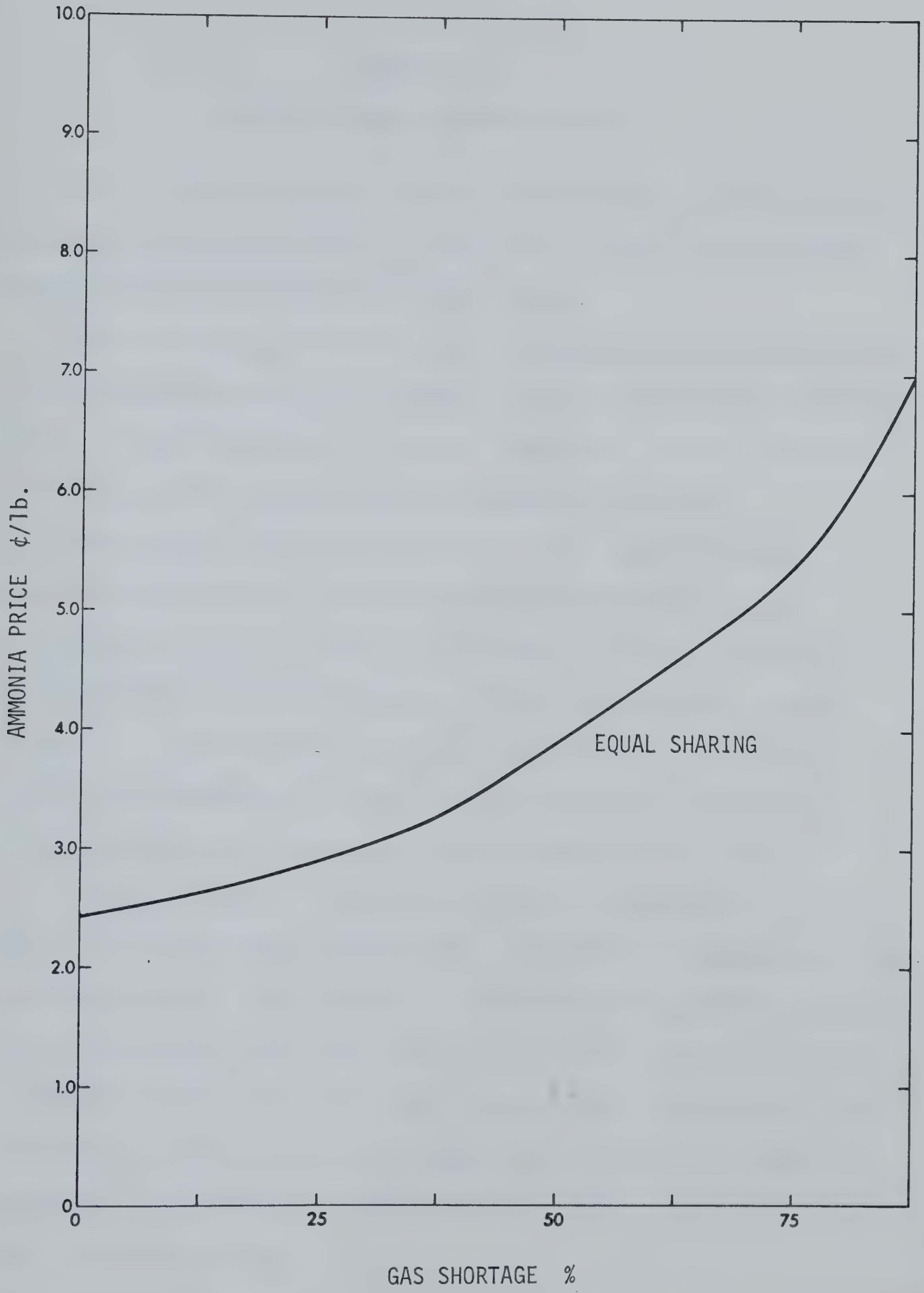

Figure 34. Effect of Rationing of Gas Supplies on Ammonia Prices.

CHAPTER VIII

ALBERTA AMMONIA DEMAND ANALYSIS

In the previous chapter, ammonia prices based on specific natural gas shortages were determined. The production costs of the largest ammonia producer dictated the commodity price.

When a commodity shortage exists, producers can sell their product at the price the market will support. Price is not based on production costs. Predicting demand for various commodities is thus important in estimating prices, particularly in the case of a shortage.

One commodity which is currently in tight supply is ammonia. Because ammonia is used almost exclusively in the manufacture of fertilizers as shown in Table 25, the demand for fertilizer must be estimated before an ammonia demand curve can be obtained. In this chapter, an ammonia demand elasticity is calculated from Alberta fertilizer consumption. The gas prices that ammonia producers can afford can then be estimated for specific ammonia demand levels.

Two points relative to the analysis must be understood at the outset. The demand prices estimated will be compared to the ammonia prices calculated in the supply analysis. The demand values, however, represent Alberta prices and the supply prices, U.S. values. However, as shown in Table 25, Alberta and U.S. ammonia consumption is very similar and the Alberta industry is just one segment of the total North American industry. The difference in ammonia market location should, therefore, not affect the analysis.

Table 25

Ammonia Use as a Percent of Total Demand

	U.S.	ALBERTA
DIRECT APPLICATION FERTILIZER	26.4	25.0
UREA FOR FERTILIZER	10.1	9.6
AMMONIUM SULPHATE	5.9	11.7
AMMONIUM PHOSPHATE	11.1	24.6
AMMONIUM NITRATE AS FERTILIZER	18.2	16.5
NITROGEN SOLNS.		1.3
+		
MIXED FERTILIZER	4.3	6.3
TOTAL FERTILIZER USE	76%	95%
NON-FERTILIZER USE (INCLUDES EXPLOSIVE, PLASTICS, CHEMICALS)	24	5
	100	100

SOURCES: (10, 39)

The other point concerns why ammonia was analyzed. Other chemicals use natural gas feed, however, predicting demand for these chemicals is extremely difficult. Ammonia is converted to end product (fertilizer) in one process step. Methanol, for example, undergoes several changes before ending up in plywood as a resin. The demand for plywood must be determined before a methanol demand curve can be obtained. Similarly, ethylene is manufactured into hundreds of end-products and the demand for each of these must be estimated. Because of the involved process in converting other chemicals to final products and the difficulty in predicting demand for these goods, only ammonia was examined.

In determining demand elasticities, two possibilities present themselves: demand is price elastic and/or income elastic. Historical data for Alberta (39, 40, 41) indicates that fertilizer consumption, at least since the early 1960's, is not linked to fertilizer price. As illustrated in Figure 35, prices of fertilizer remained relatively stable at about \$80 to \$100/ton through 1973, but demand fluctuated dramatically. Determining an income elasticity was obviously the more accurate alternative.

From a preliminary analysis, it was apparent that the farmer, the principal consumer, purchases fertilizer on the basis of his cash grain income from the preceding year. This phenomenum is shown graphically in Figure 36. Since the early 1960's, which was the beginning of extensive manufactured fertilizer consumption in Alberta, fertilizer sales rose and fell as grain income similarly changed at constant fertilizer prices (39, 40, 41). This implies that fertilizer

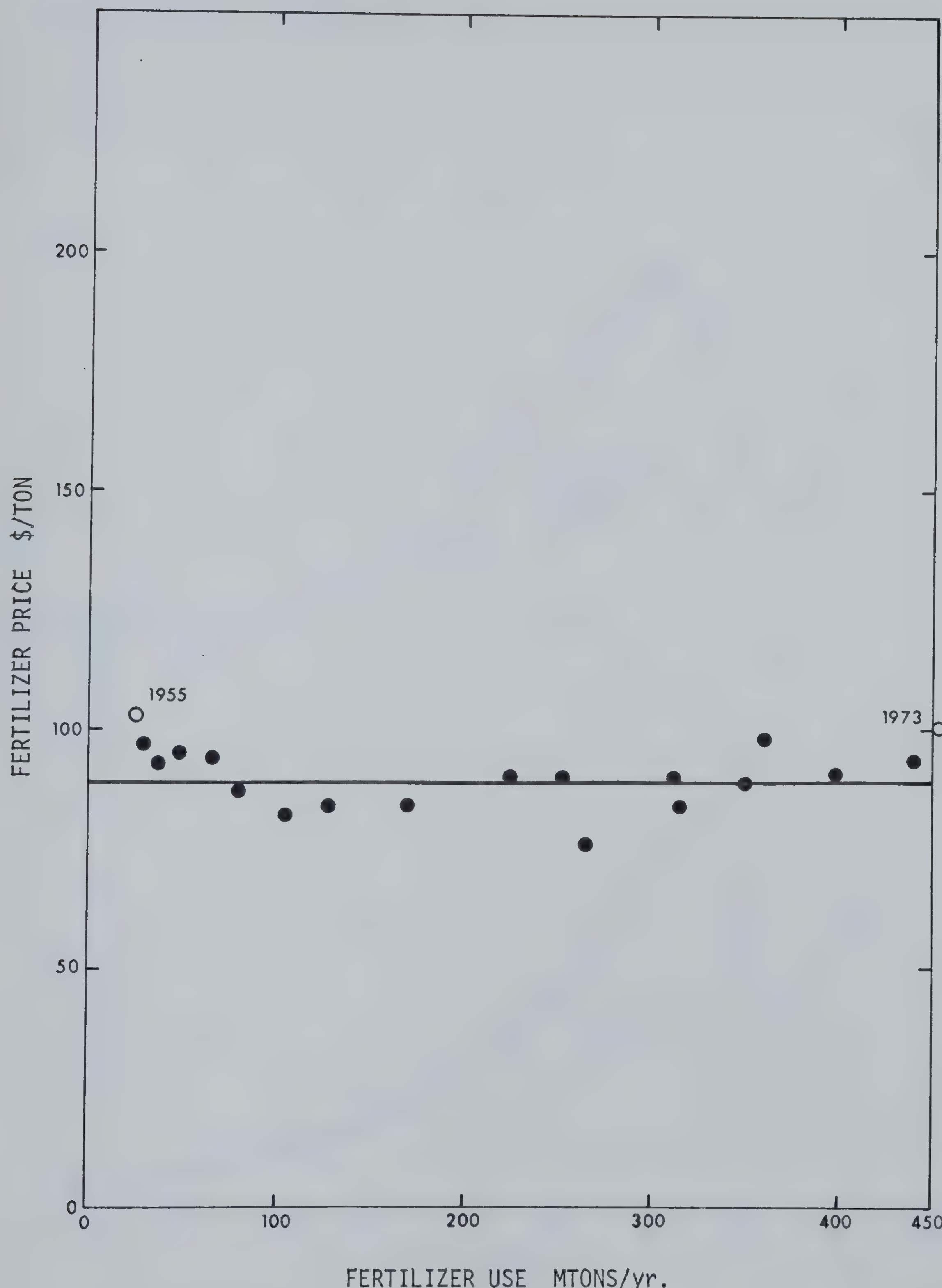

Figure 35. Fertilizer Price and Use

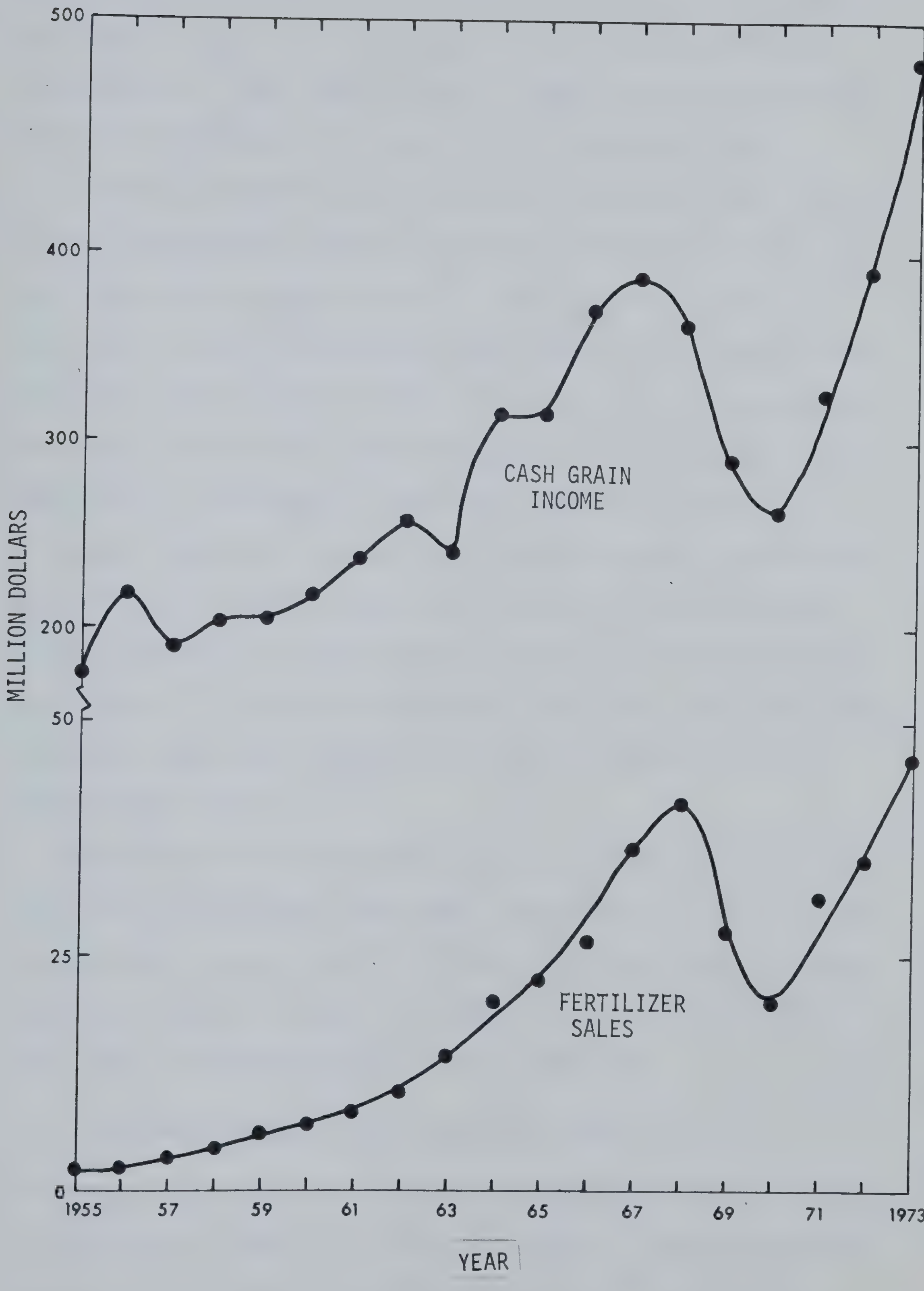

Figure 36. Historical Alberta Cash Grain Income and Fertilizer Sales

demand is income elastic. As illustrated in Figure 36, 1968 was a peak year for cash grain income, but fertilizer sales peaked the following year. Hence the cash grain income from the previous growing season determined fertilizer sales for the current year.

The dollar value of fertilizer sales equals price times fertilizer consumption and similarly cash grain income is the total crop sales times the average price of all crops produced. Some crop production is used as feed on the farm producing the crops, but this constitutes non-cash grain income. Fertilizer price is the cost of fertilizer to the farmer, and includes distribution charges from the plant gate to the consumer. Total crop sales equal the sales of all grain, vegetables, and oilseeds in million bushels, and are distinguished from livestock sales, which comprise the remainder of farmer's cash income. Crop sales are related to yield, thus fertilizer usage is a function of crop price, fertilizer price, and yield. If the functional relationships can be approximated, a fertilizer demand follows directly.

Fertilizer sales were plotted against cash grain income (39, 40, 41) to obtain the linear relationship represented in Figure 37. The best straight line was visually fitted to the data plotted. Knowing a specific cash grain income, fertilizer sales are established by this line. The equation of the line is as follows:

$$\text{Fertilizer sales} = \frac{1}{6.1}\,(\text{Cash grain income} - 175)$$

where fertilizer sales and income are in millions of dollars. When the definition of fertilizer sales and income are incorporated into the above relationship, the equation reduces to the following:

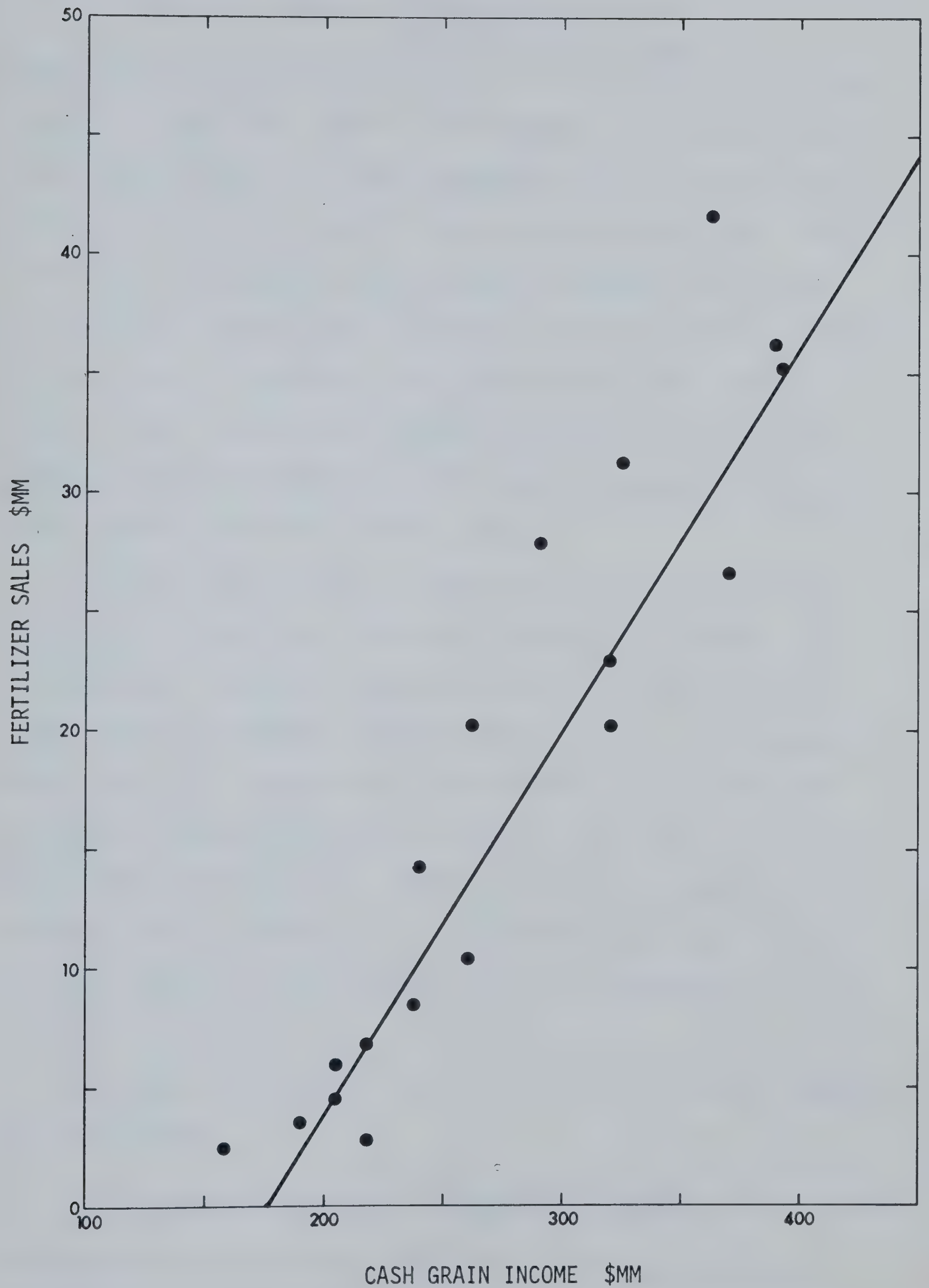

Figure 37. Fertilizer Sales vs. Cash Grain Income

$$\text{Fertilizer demand} = \frac{(\text{crop price})(\text{yield})-175}{6.1\ (\text{fertilizer price})}$$

where demand is in MM Tons/yr, crop price is in $/bushel, fertilizer price is in $/Ton, and yield is in MM bushels. Obviously, if yield can be approximated, fertilizer consumption can be determined from the above equation for specific grain and fertilizer prices. Since fertilizer is composed of mainly nitrogen, phosphate, and potash, the demand for each of these commodities can also be derived. Nitrogen, of course, is applied to the ground in many forms, including ammonia, urea, nitrates, and nitrogen solutions, but all of these nitrogen forms are manufactured from anhydrous ammonia. Total crop yield therefore determines ammonia demand.

Estimating yield, however, proved to be a difficult task. A fundamental assumption was required to continue the analysis. It was postulated that total crop yield (grains, oilseeds, and vegetables) would be constant at 300 MM bushels per year. The average total crop sales in Alberta over the pre-fertilizer era from 1906 to 1960, was about 300 MM bushels annually (40). Yield has now been eliminated from the analysis. Fertilizer (ammonia) consumption is therefore solely a function of crop and fertilizer prices. The reasons for assuming a constant crop yield will be presented at the conclusion of the analysis.

The general fertilizer consumption equation has now been reduced to the following:

$$\text{Fertilizer demand} = \frac{1}{6.1}\left(\frac{300\ (\text{crop price})-175}{\text{fertilizer price}}\right)$$

where demand is in MM Tons/yr, crop and fertilizer prices are in $/bushel, and $/ton, respectively. From the above equation, fertilizer

consumption for $1 and $2/bushel crops was calculated for fertilizer prices varying from $50 to $300/Ton, as shown in Table 26. Fertilizer demand was plotted against fertilizer price to obtain the demand curves illustrated in Figure 38. Average crop prices have historically fluctuated between $1 and $2/bushel (39), therefore these values were used in the analysis.

Figure 38 shows that increasing fertilizer price results in decreased demand. Historically, however, fertilizer prices remained relatively stable as demand fluctuated. It is also interesting to note that higher crop prices induce greater fertilizer consumption. High grain prices therefore benefit both the farmer and the fertilizer manufacturer.

Since this study is concerned with ammonia consumption, the nitrogen component of fertilizer is of particular interest. Nitrogen (N) formed about 26% by weight of the total fertilizer sold in Alberta during the early 1970's (39, 41). Assuming the nitrogen component of fertilizer consumed remains constant, the fertilizer demand curve is readily converted to a nitrogen demand curve by multiplying fertilizer use by a .26 factor. Nitrogen comprises 82% of ammonia, so ammonia consumption equals nitrogen use divided by .82. Ammonia demand can now be calculated for specific fertilizer usage. It remains to convert fertilizer price to ammonia price to obtain an ammonia demand elasticity.

Historically, the two major components of fertilizer, ammonia and phosphorus, have been about the same price, therefore it was assumed that fertilizer price was equivalent to ammonia price. A recent publication (42) showed that 1975 prices of phosphate will be

Table 26

Effect of Fertilizer Price on Fertilizer Demand

FERTILIZER PRICE (DELIVERED)	FERTILIZER DEMAND M TONS	
$/TON	$/BUSHEL	$2/BUSHEL
50	410	1390
100	205	697
150	137	465
200	102	350
250	82	283
300	68	233

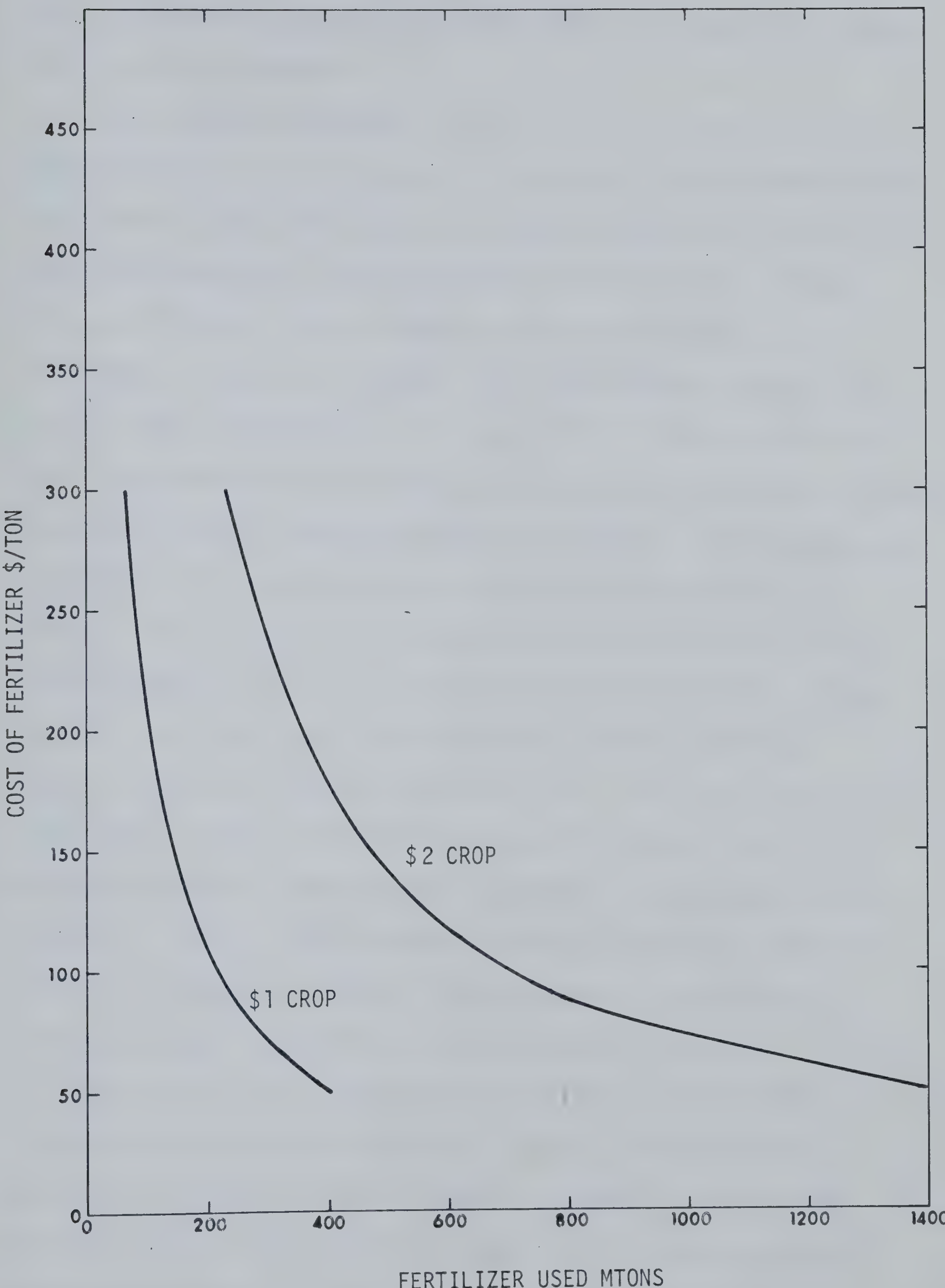

Figure 38 . Effect of Crop Price on Alberta Fertilizer Demand

\$180 - \$195/TON and ammonia prices \$220/TON and up, hence this assumption is not unreasonable.

Based on this assumption, the ammonia prices listed in Table 27 were calculated. The corresponding nitrogen and ammonia demand levels for \$1 and \$2 crops were derived from Table 26 fertilizer consumption, using the appropriate conversion factors noted previously. Ammonia price was plotted against consumption to obtain the demand curves illustrated in Figure 39. Actual 1974 Alberta ammonia capacity (16) is also shown in the figure. It is apparent from studying the figure that Alberta consumption should have been much less than ammonia capacity. This implies that a considerable amount of ammonia is marketed outside of Alberta. As an example, in 1971 Canada exported 160 M Tons of ammonia, mostly to the U.S. (43), and Alberta contains about 40% of Canadian capacity (27). It is also interesting to note that a doubling of crop prices from \$1 to \$2 increases ammonia demand by a factor of three for a specific ammonia price. Crop prices increased dramatically in 1974, to about an average of \$3/bushel, hence it is obvious from Figure 39 that ammonia consumption jumped significantly last year. Indeed, it was reported by Sherritt Gordon Ltd. (42) that fertilizer production in Western Canada jumped by 250,000 tons in 1974, even though no significant plant expansions occurred.

At this point, the reasons for eliminating crop yield from the income analysis should be presented. Yield is a function of many variables, including soil type, weather, and amount of fertilizer applied. Because these parameters vary throughout the province and because yield response to these variables is extremely difficult to determine, a general relation correlating yield to these various

Table 27

Ammonia and Nitrogen Demand

AMMONIA PRICE $/TON	NITROGEN DEMAND M TONS		AMMONIA DEMAND M TONS	
	$1 CROP	$2 CROP	$1 CROP	$2 CROP
50	106.6	362	129	438
100	53.3	180	64.5	219
150	35.6	120	43.1	146
200	26.5	90	32.1	110
250	21.3	73.6	25.8	89
300	17.7	60.6	21.4	73.3

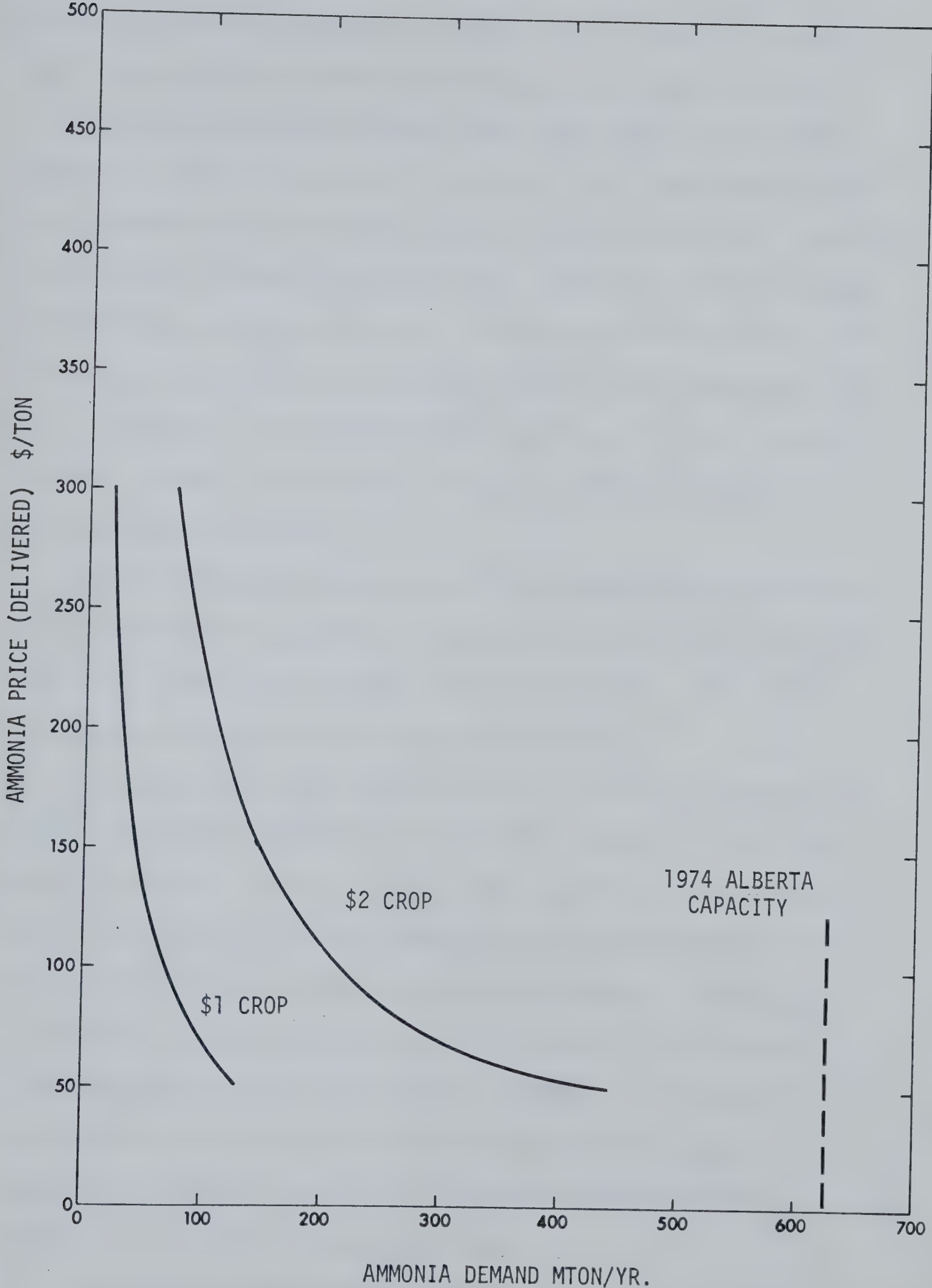

Figure 39. Effect of Crop Price on Alberta Ammonia Demand

factors could not be derived. For this primary reason, an average crop yield of 300 MM bushels per year was used in the analysis.

Some secondary points should also be mentioned. One is that fertilizer application generally increases yield, but adverse weather can negate the effect of fertilizer. In fertile soils, crop response to fertilizer is almost negligible (44). Similarly, although several studies have concluded that yield is a function of June rainfall (45, 46), early frost or hail can severely reduce yields even though rainfall is plentiful. The unpredictability of each of these variables and their complex interdependence also influenced the decision to use an average crop yield.

All of the ammonia demand analysis was based on historical fertilizer consumption in Alberta. There is no reason to believe, however, that farmers will deviate from past behavior. Figure 39 thus represents a possible future ammonia demand curve.

The cash grain income approach was not necessarily required to predict fertilizer consumption. Alternative methods include a net income elasticity, a risk analysis, and a system based on marginal return. The net income method was considered, but because of the accounting procedure used, was less straight forward, therefore, the analysis was discontinued. The risk analysis (47) involves predicting future crop yields based on weather. Farmers would purchase fertilizer in anticipation of good growing seasons. However, the process is extremely difficult because predicting weather is a hazardous occupation, at best.

The marginal return approach, however, is recommended by the Department of Agriculture (48). It is recommended that fertilizer

be applied to the ground as long as the expected return is greater than two to one. In other words, for every extra dollar of fertilizer applied, the farmer receives at best $2 in terms of increased yield. The 2:1 ratio accounts for the risk of crop failure. For this analysis, the response of crops to increased yield must be known. In the income study, the response was eliminated because of the variance in response to soil types and weather. However, to demonstrate the marginal return system, Department of Agriculture data for the Wetaskiwin area will be used (48).

The response of barley and oats to nitrogen application for a constant phosphate load of 50 lb/acre is illustrated in Figure 40. Crop response is affected by both the nitrogen and phosphorus levels in the soil, and 50 lb/acre of phosphate is the recommended application in the Westaskiwin area.

Using the response data plotted in Figure 43, the marginal return to the farmer for various levels of nitrogen application on barley was calculated as shown in Table 28. Nitrogen and phosphate prices of $270 and $180/Ton, respectively, as quoted by Sheritt Gordon for 1974 (42), were used in determining fertilizer costs. When 60 lb/acre of nitrogen is applied to barley, yield is increased about 25 bushels/acre as shown in Table 26. The increased yield from the 50 lb/acre level is only about 3 bushels/acre, however. Thus the marginal return would be about 2 to 1 for $1 barley and a 60 lb/acre nitrogen application. This would be the recommended fertilizer use. Similarly, for $2 barley, the recommended application would be 90 lb/acre of nitrogen, equivalent to 109 lb/acre of ammonia.

A comparison of this analysis to the income study might prove

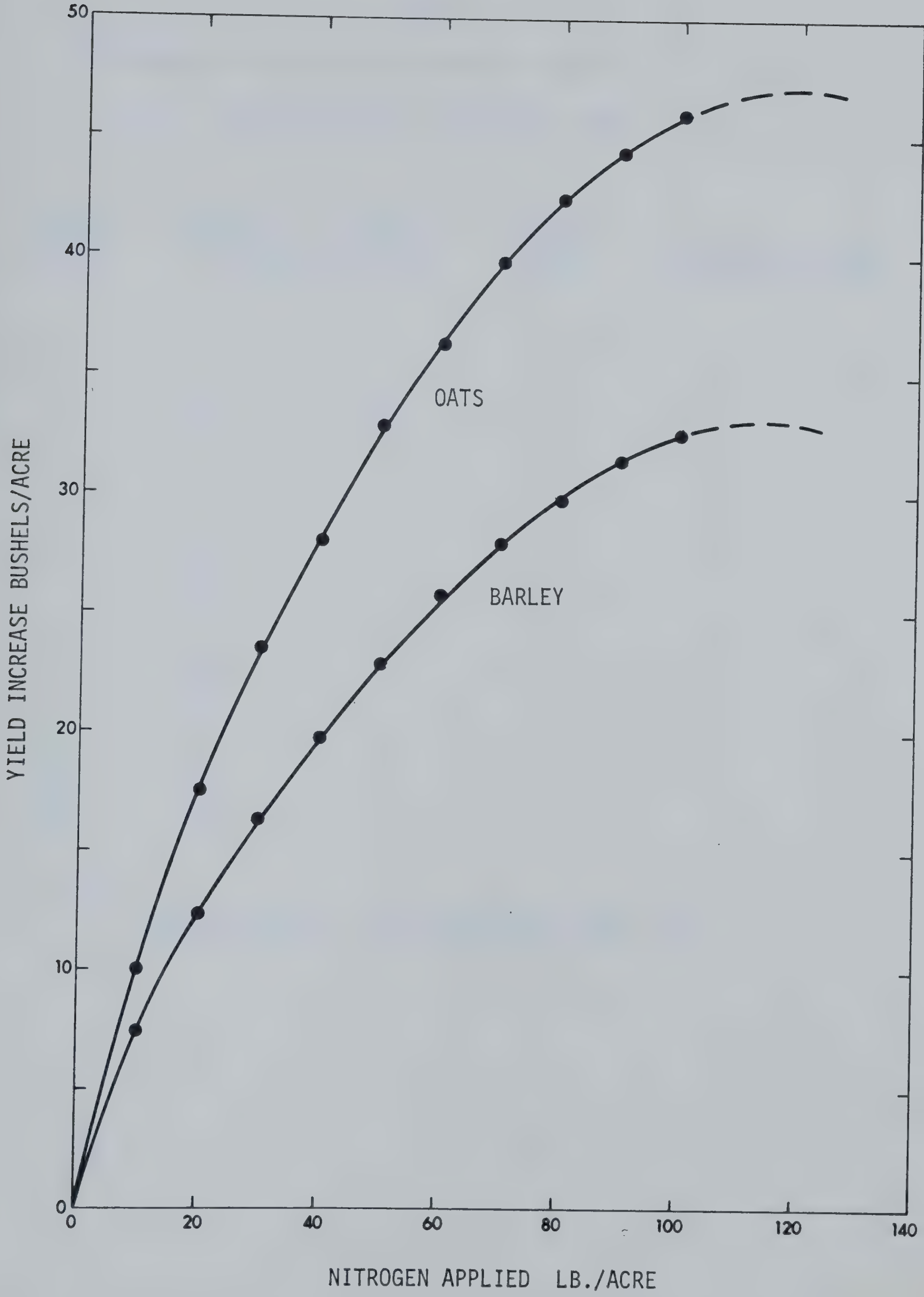

Figure 40. Crop Response To Nitrogen Application

Table 28

Influence of Crop Price on Marginal Return to the Farmer

Basis: Constant Load of 50 lb/acre P_2O_5 on Barley

NITROGEN APPLIED LB/ACRE	INCREASED YIELD (BUSHEL/ACRE)	CHANGE IN YIELD (BUSHEL/ACRE)	CHANGE IN COST/ ACRE	MARGINAL RETURN $1 CROP	MARGINAL RETURN $2 CROP
0	0	0	0	0	0
10	7.5	7.5	1.35	5.55	11.10
20	12.4	4.9	1.35	3.63	7.26
30	16.4	4.0	1.35	2.98	5.96
40	19.8	3.4	1.35	2.51	5.02
50	23.0	3.2	1.35	2.37	4.74
60	25.8	2.8	1.35	2.07	4.14
70	28.0	2.2	1.35	1.63	3.26
80	29.8	1.8	1.35	1.33	2.66
90	31.5	1.7	1.35	1.26	2.52
100	32.5	1.0	1.35	.74	1.48

$$\text{MARGINAL RETURN} = \frac{\text{DOLLAR CHANGE IN CROP YIELD}}{\text{INCREASED COSTS}}$$

interesting. For $2 grain and $270/Ton Nitrogen, the corresponding ammonia demand was calculated to be 105 MTons by the income analysis. In 1973, 5.2 million acres of Alberta soil was fertilized (49), therefore 105 MTons is equivalent to 40 lbs/acre of ammonia. The comparable usage based on marginal return was 109 lbs/acre. The difference lies in the fact that the cash grain correlation was based upon total fertilizer demand by all Alberta farmers. The soil test (marginal return) analysis is currently used by only about 5% of Alberta farmers (50). Hence, fertilizer demand estimated using this method would not be realistic. For both systems, however, fertilizer consumption hinges on the price of grain. It is apparent that the fertilizer industry is a boom or bust operation, depending on grain prices.

Gas Prices

Having determined ammonia demand elasticities, the next step in the analysis is to estimate the gas prices ammonia producers can afford. From the introductory supply-demand analysis, this gas price is equivalent to the ammonia market value minus the costs of producing that commodity. The demand curve dictates both the price of ammonia and the allowable price of natural gas.

The problem which must be solved is to relate ammonia price to natural gas price. Because ammonia is manufactured from natural gas, natural gas prices are proportional to ammonia prices. The proportionality constant must be derived. Although it is relatively simple to convert ammonia consumption to natural gas requirements on the basis of 17.5 cubic feet of gas per pound of ammonia, predicting natural gas prices involves several subtleties.

The ammonia prices plotted in the demand curves of the previous section equal delivered prices to the farmer. Plant gate costs, however, represent the costs of production. Thus plant gate price determines the gas price that producers can afford. The costs incurred in shipping ammonia from the plant gate to the consumer must be approximated.

Typical ammonia distribution costs are listed in Table 29. The values indicated were quoted in the Chemical Economics Handbook (10). Alberta ammonia producers were reluctant to reveal their distribution costs, hence the costs tabulated were used.

Table 29

Anhydrous Ammonia Distribution Costs

ITEM	COST $/TON
PRODUCTION COST	50
STORAGE	8
FREIGHT TO DEALER	5
FREIGHT TO FARMER	5
DEALER COMMISSION @10%	7
TOTAL DELIVERED COST TO FARMER	~75 $/TON

Using the data listed in Table 29, delivered anhydrous ammonia prices were converted to plant gate prices as shown in Table 30. The gas requirements tabulated equal the ammonia demand obtained from the income analysis multiplied by a factor of 17.5 cu. ft. per pound of ammonia. The gas prices indicated equal the difference between production costs and the allowable plant gate price of ammonia, which is dictated by the demand curve. Production costs were estimated for

Table 30

Natural Gas Demand for Ammonia Production

NH_3 PRICE (DELIVERED) $/TON	NH_3 PRICE (PLANT GATE) $/TON	GAS PRICE $/MCF	GAS REQUIREMENTS BCF/YR $1 CROP	$2 CROP
50	27	0	4.49	15.2
75	50	0.50	3.36	11.4
100	72	1.13	2.24	7.62
150	117	2.42	1.50	5.08
200	162	3.72	1.12	3.83
250	207	5.00	0.90	3.10
300	252	6.30	0.74	2.55

a 1500 TPD ammonia plant and include a 20% return to the producer. For example, for a plant gate price of \$162/Ton, \$35/Ton represents the cost of production excluding natural gas, leaving \$127/Ton as the allowance for gas supplies. A cost of \$127/Ton is equivalent to \$3.72/Mcf natural gas. The gas prices listed are thus the amount that producers can afford, but retain a 20% profit margin.

The data of Table 30 are presented graphically in Figure 41. As shown, a doubling crop of prices increases gas demand by more than threefold, at a constant gas price. From Figure 41, it is also evident that rising gas prices cause reduced gas consumption, reflecting decreased ammonia demand.

To summarize the ammonia analysis, Figure 42 was drawn. This figure shows the actual supply and demand curves calculated for ammonia. The ammonia supply lines represent breakeven production costs for the various plant sizes used in the plant construction operating with gas prices varying from \$0 - \$4.50/Mcf. Breakeven price is used in the same context as in the market analysis. The equilibrium point indicates full natural gas supply and a zero gas price.

From Figure 42, it is obvious that the equilibrium point shifts when crop prices change. The gas price that ammonia producers can afford increases dramatically when crop prices rise. For \$1 crop, the equlibrium points equals 1.4¢/lb of ammonia, corresponding to zero natural gas cost. A doubling of crop prices implies that ammonia prices would increase to 7.5¢/lb for the same consumption level,

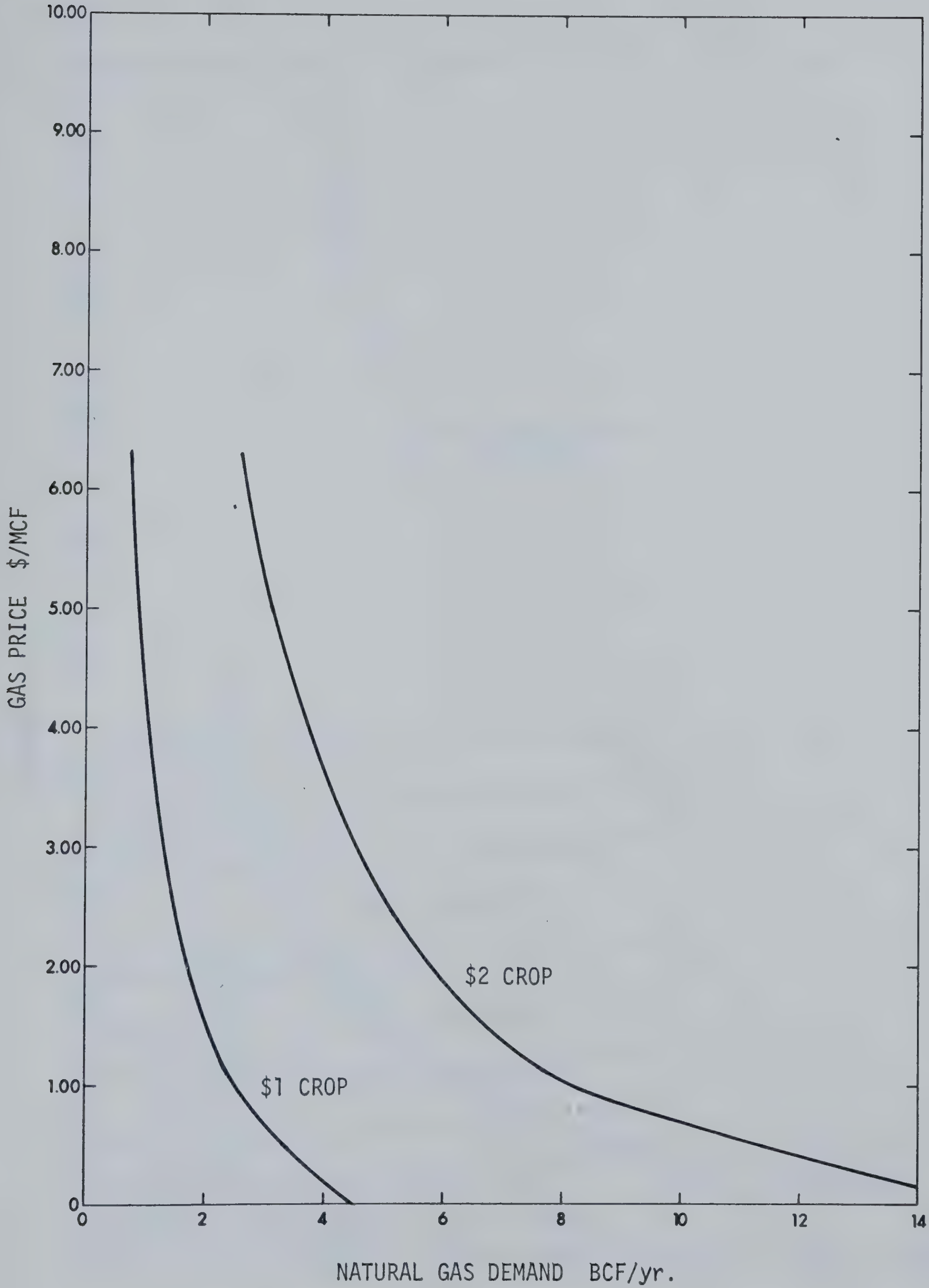

Figure 41. Effect of Crop Price on Gas Price Ammonia Producers Afford

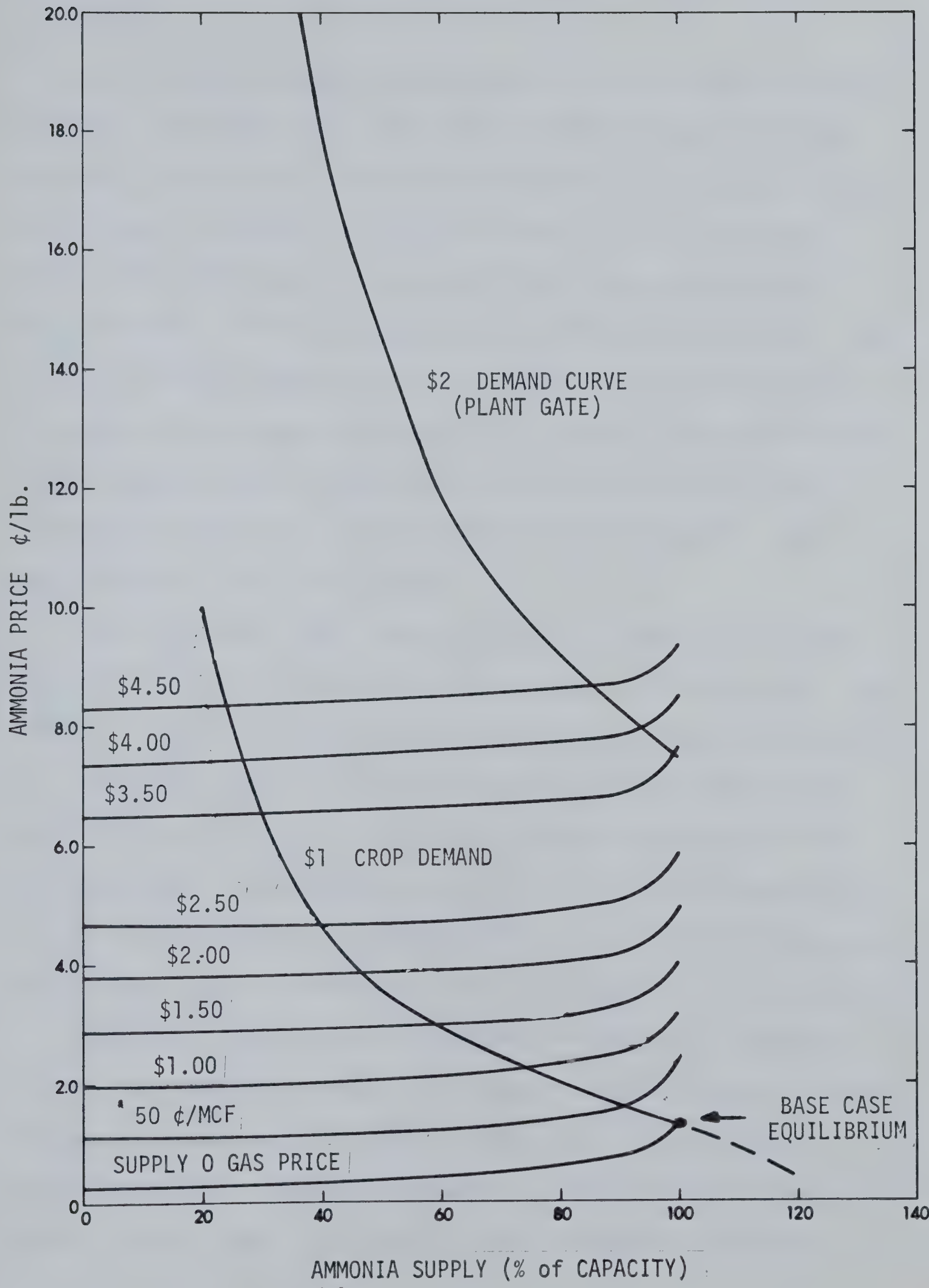

Figure 42. Composite Ammonia Supply And Demand

and gas prices that ammonia producers could afford would be in excess of \$3.50/Mcf.

The influence of gas price on fertilizer use is clearly evident in Figure 43. As gas price increases to \$2/Mcf, Alberta fertilizer consumption should drop to about 600 MTons per year for grain prices of \$2/bushel, if historical trends continue. It should be noted, however, that 1973 demand was only 500 MTons for a crop price of about \$2 bushel (39), even though gas prices were about 25¢/Mcf. The discrepancy arises because gas prices determined by the demand analysis are prices producers can afford, but retain a 20% profit margin. In 1973 ammonia producers made much larger profits because of the existence of long-term, inexpensive natural gas contracts. Hence, the difference in gas prices exists.

When crop prices drop, the gas price that ammonia manufacturers can afford decreases substantially for a constant fertilizer use. For example, a fertilizer producer can afford \$3.00/Mcf gas for \$2 crops at a consumptive level of 400 MTons, but only about 10¢/Mcf for \$1 crop. Thus ammonia producers would be reluctant to negotiate long-term natural gas contracts because grain prices fluctuate dramatically. It is also evident from studying Figure 46 that there is an upper limit to the amount of fertilizer purchased, even for zero gas costs.

The effect of gas prices on the ammonia producer has now been defined. How gas price affects the farmer is also of interest, since farmers are the principal consumers of ammonia. In the marginal return analysis, it was shown how ammonia application affects the yield of various crops in a specific area. Increased application

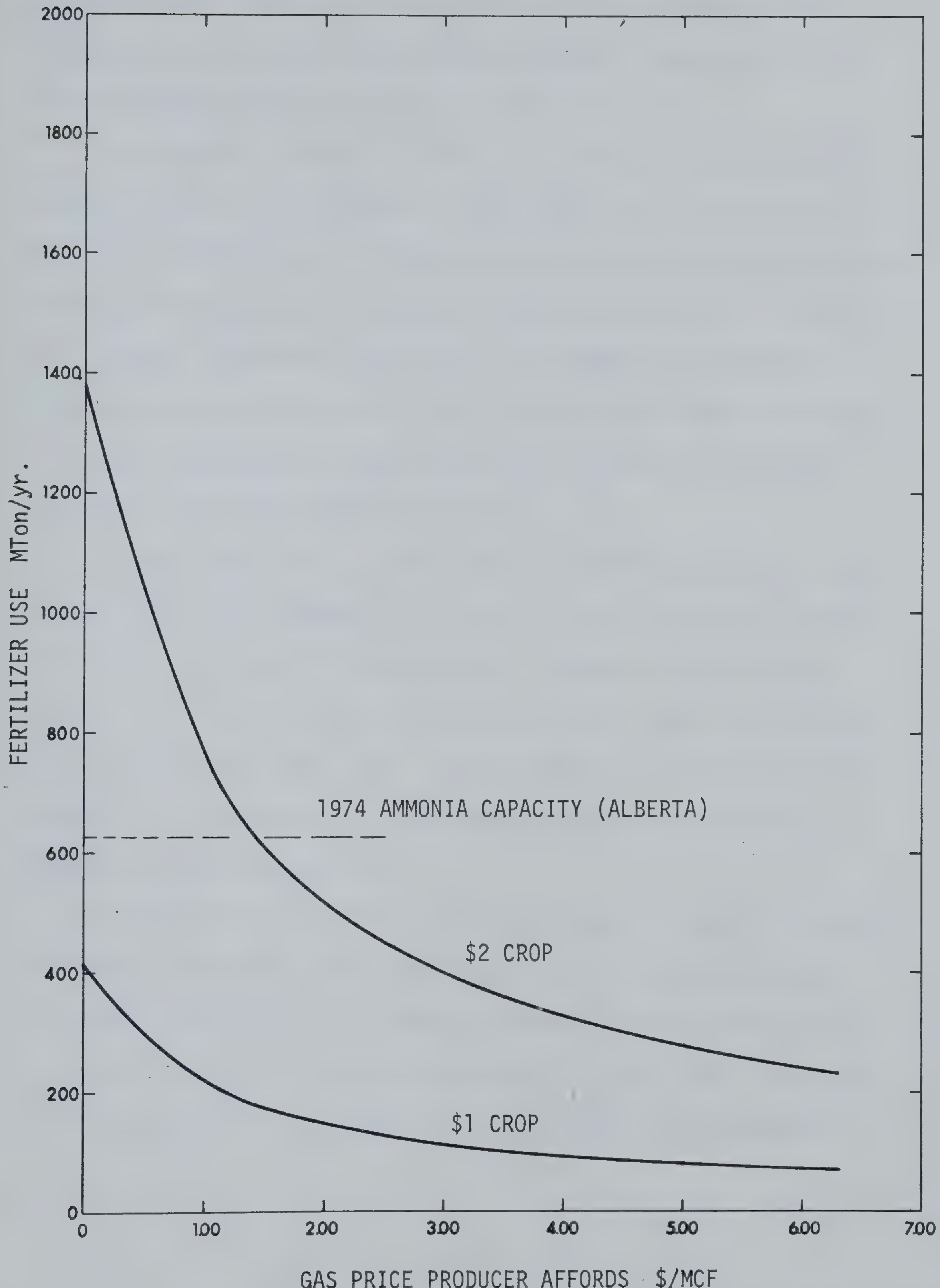

Figure 43. Effect of Gas Price on Fertilizer Use

increased yields, and thus increased the value of farmer's crops. Rising gas prices induce lower ammonia demand. Consequently, gas prices influence the total value of crops produced.

This behavior is shown in Table 31. Yields tabulated were obtained from the soil test analysis for barley and a constant phosphate load of 50 lbs/acre. Application rates for nitrogen were estimated by dividing total nitrogen consumption, as listed in Table 28, by a constant value of 5.2 MM acres. 1973 fertilized acreage in Alberta was 5.2 million acres (49), therefore this number was employed in the calculations. Crop value equals increased yield times crop price times total fertilized area.

The data from Table 31 were plotted to obtain the curves shown in Figure 44. As illustrated, rising gas prices result in a drop in crop value, for a specific grain price. However, if grain prices increase, the resulting jump in yield values will more than compensate for the rise in gas costs. As an example, a $1 crop price and 50¢/Mcf gas corresponds to an increased crop value of $86 MM, or roughly 1/4 the $2 crop value.

Of course, all of the above analysis hinges on favorable weather conditions. Otherwise, there would be limited response of crops to ammonia application. The previous analysis was presented mainly to show the residual effects of gas prices on the farmer, and as an alternative method of analysis to the cash grain income approach.

Table 31

Effect of Gas Price on Yield

Basis: Constant P_2O_5 Load of 50 lb/Acre

GAS PRICE $/MCF	NITROGEN APPLIED LB/ACRE		INCREASED YIELD BUSHELS/ACRE		INCREASED CROP VALUE $MM	
	$1 BARLEY	$2 BARLEY	$1 BARLEY	$2 BARLEY	$1 BARLEY	$2 BARLEY
0.00	40.8	138	20	33	104	343
0.50.	30.6	104	16.5	33	86	343
1.13	20.4	69	12.5	27.5	65	286
2.42	13.6	46.3	9.0	21.5	47	224
3.72	10.1	34.8	7.5	18.0	39	187
5.00	8.2	28.2	6.0	15.5	31	161
6.30	6.8	23.2	5.5	13.5	29	140

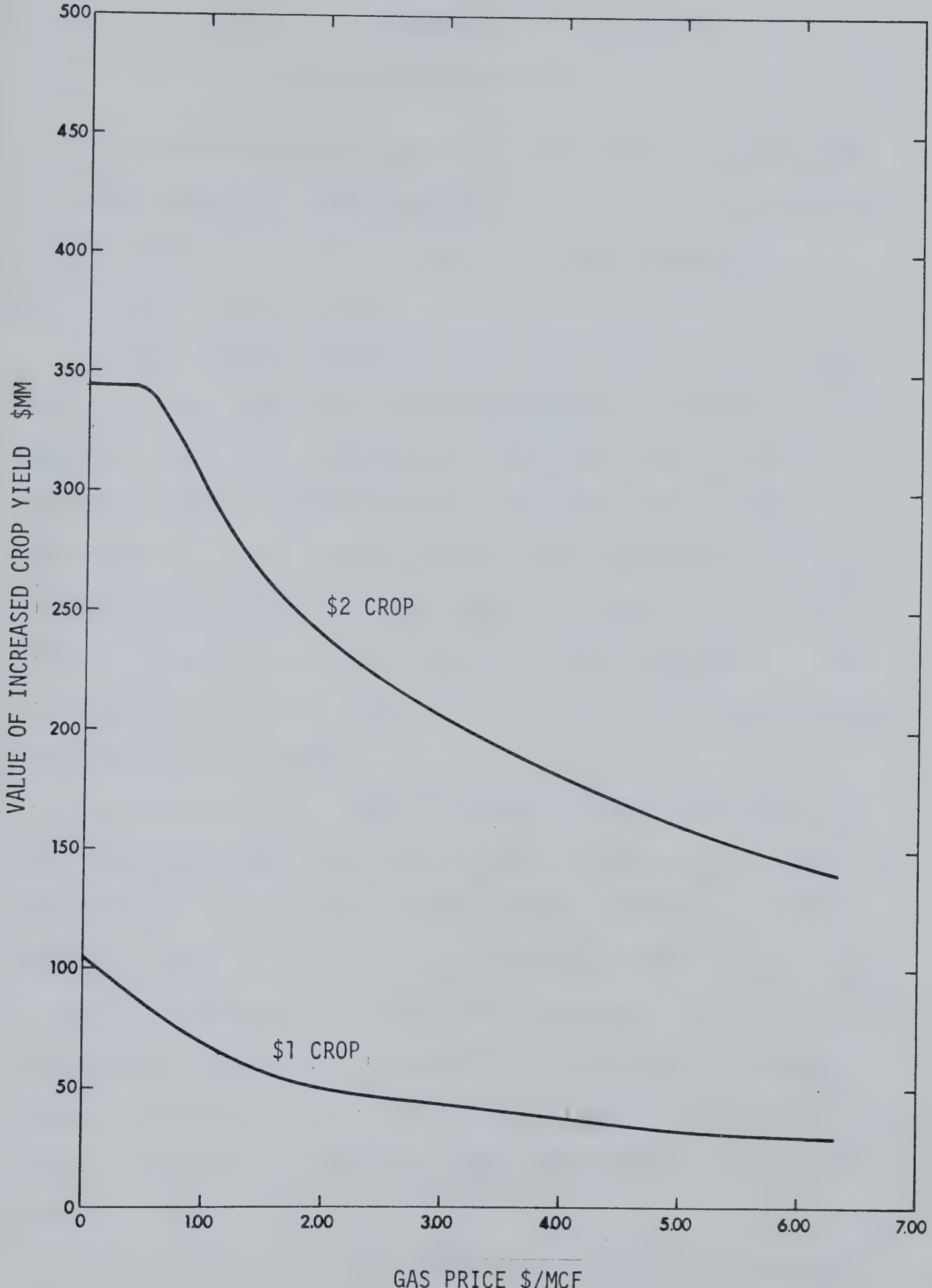

Figure 44 Effect of Gas Price on Yield

CHAPTER IX

METHANOL SUPPLY ANALYSIS

The previous chapters determined ammonia supply and demand and from these estimates, predicted natural gas supply and demand curves. It seems logical to extend the analysis to other commodities manufactured from natural gas.

However, although the natural gas supply models can be readily applied to these commodities, predicting demand is extremely difficult. Ammonia is used almost exclusively as fertilizer, hence it was relatively simple to determine ammonia demand from fertilizer consumption. As noted earlier, however, other commodities such as methanol require several process steps before being converted into finished products. Estimating demand for these end-products is very time-consuming. For this reason, the demand for chemicals other than ammonia was not calculated.

The purpose of this chapter is merely to apply the plant construction and equal gas sharing concepts to the methanol industry, since methanol is the second largest chemical natural gas consumer (after the ammonia industry). The construction model will be applied to simulate historical price-production data, which approximates long term methanol supply, and is assumed to be influenced by consumer demand. The equal sharing of natural gas supplies can be applied to predict the effect of short term natural gas shortfalls on methanol prices.

The price of chemicals has generally decreased since the early 1950's due to increased demand which has prompted the construction of large, efficient chemical plants. This pattern of decreasing price

as production increased has been evident in the methanol industry, as shown in Table 32. The figures shown in the table are historical data (11) for the years 1950 to 1970. Methanol price shown is the unit sales value for these years, which was discounted at 4% to 1977 dollars to obtain the figures listed in the discounted price column. A 4% value was chosen because the Nelson cost index indicates that plant construction costs have increased by this average amount between 1950 and 1969 (37). The year 1977 was chosen as a reference point because the methanol price calculated for various gas shortages using the equal sharing model approximate 1977 production costs of a 1300 MM lb/yr plant. A common base then exists for comparing the two feedstock supply levels: the case of 100% gas supply where prices historically dropped due to changing technology and the future trend of higher prices induced by natural gas shortage.

As indicated in the model description, obtaining a plant size is foremost in applying the construction analysis. Table 33 shows the results of the construction analysis based on an 8.5% annual methanol demand increase, as the Chemical Economics Handbook data for the 1960's indicates. To briefly outline this model, plant size was assumed to equal market growth in a particular year and new plants were assumed to be built only when production costs were less than existing plants. The methanol price shown equals the production costs of the largest plant size predicted for each year. In 1960, for example, the largest plant size predicted was 300 MM lb/yr, and 2.6¢/lb would be the production costs of this plant based on a 1960 gas cost of 50¢/Mcf (38). Methanol price was discounted at 4% to 1977 to obtain the entries in the last column of Table 33. Discounted methanol price was then plotted

Table 32

Historical Methanol Price-Production Data

YEAR	PRODUCTION	PRICE	DISCOUNTED 1977 DOLLARS
1950	901.6 MM LB	3.27 ¢/lb	9.43 ¢/lb
1955	1343.6	3.77	8.93
1960	1965.9	3.62	7.05
1965	2368.6	3.15	5.04
1970	4944.5	2.66	3.49

Table 33

Simulated Methanol Prices and Production

YEAR	PRODUCTION*	METHANOL PRICE	DISCOUNTED (1977) PRICE
1950	901.6 MM LB	3.27 ¢/LB	9.428 ¢/LB
1954	1249.0	2.815	6.938
1960	2038.0	2.616	5.096
1964	2825.0	2.428	4.043
1969	4248.0	2.231	3.053

*Assumes 8.5% annual increase

against production to obtain curve (1) in Figure 45. Historical data from Table 32 are plotted as curve (2) in the figure. As illustrated, the curve obtained from the plant construction model parallels the historical methanol price-supply line, although predicted methanol prices are generally lower than historical for a specific production level. However, if the slopes of the two curves on log paper were the same, the elasticity of demand would be the same. For example, a 33% rise in production from 3000 to 4000 MM lb/yr decreased the methanol price by about 20% in both the simulated and historical cases. Recall that historical data represent the unit sales value of methanol and include transportation charges to consumers. Prices calculated by the plant construction analysis are plant gate prices. A constant transportation charge of 0.6¢/lb (1970) was assumed and historical prices were replotted, subtracting this value to obtain curve (3) in Figure 45. A cost of 0.6¢/lb approximates the weighted average transportation charges to methanol consumers (11) and gives the best correlation between historical and predicted values.

An alternative method of predicting plant sizes was then examined. Recall that plant size was assumed equal to market growth, which was 8.5% annually in the case of methanol. The 8.5% increase, however, represented an average value, since actual production increased from year to year. Therefore historical production data were used as input for the construction analysis. New plants, if the criteria for construction was satisfied, were assumed equal in capacity to the increase in production since the previous plant was built. This analysis resulted in larger plant sizes being predicted and hence slightly lower methanol prices than the previous procedure. Results are listed in

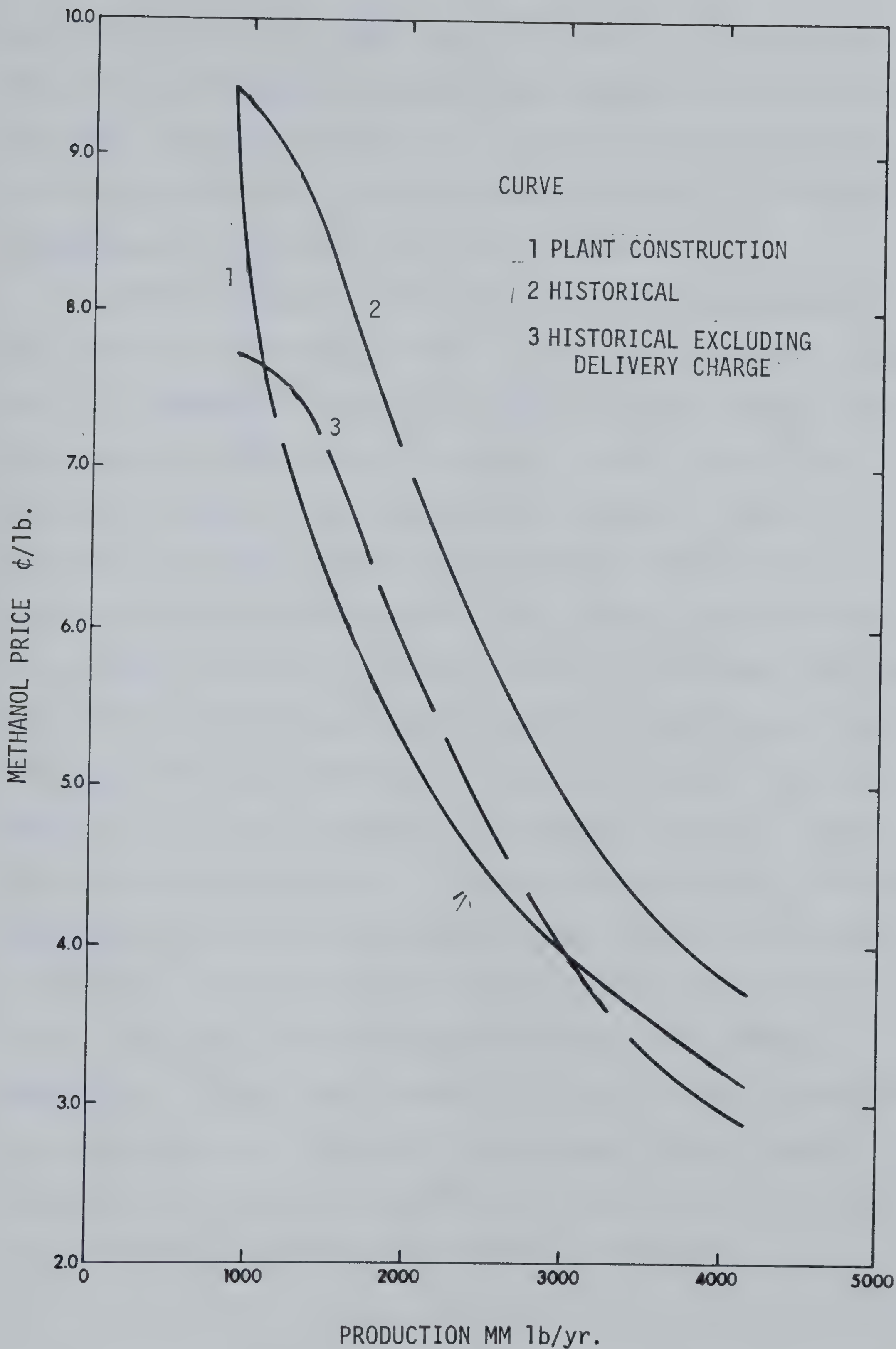

Figure 45. Comparison Of Historical Methanol Price-Production Data and Supply Model Results Calculated Using 8.5% Annual Production Increase

Table 34, from which the plant construction curve in Figure 46 was obtained. As illustrated, methanol prices calculated were consistently lower than the historical prices for a specific production, but the trend of lower commodity prices induced by cheap natural gas and the construction of large, efficient plants is apparent.

The previous analysis is concerned solely with the concept of 100% feedstock availability. Prices declined due to abundant methanol supply and economies of scale of the large producers. Suppose, however, that severe gas demand forces curtailment of natural gas to large industrial consumers, such as the methanol industry. Figure 47 illustrates the effect of various gas shortages on the price of methanol, determined by applying the equal sharing system. Methanol prices plotted correspond to production costs of the largest Gulf Coast plant having a 1300 MM lb/yr capacity and using 50¢/Mcf natural gas. The figure shows that methanol price would only increase from 1.9 to 3.0¢/lb for a 50% gas curtailment to all methanol producers, based solely on costs of production. Of course, a uniform 50% gas curtailment implies that 50% of the normal methanol supply will not be available to consumers. Competitive market forces would then drive the price of methanol up to the equilibrium level determined by the methanol demand curve. In any event, whereas historically prices have declined due to the abundance of cheap gas feedstocks and the development of large, efficient plants, the uncertainty of future natural gas supply may cause chemical prices to rise to unprecedented levels.

Table 34

PRICE SIMULATION USING HISTORICAL PRODUCTION DATA

YEAR	PRODUCTION	PRICE	DISCOUNTED TO 1977
1950	901.6 MM LB	3.27 ¢/LB	9.428 ¢/LB
1956	1224	2.24	6.27
1968	1592	2.345	5.34
1960	1966	2.479	4.83
1964	2632	2.175	3.62
1969	4148	2.078	2.85

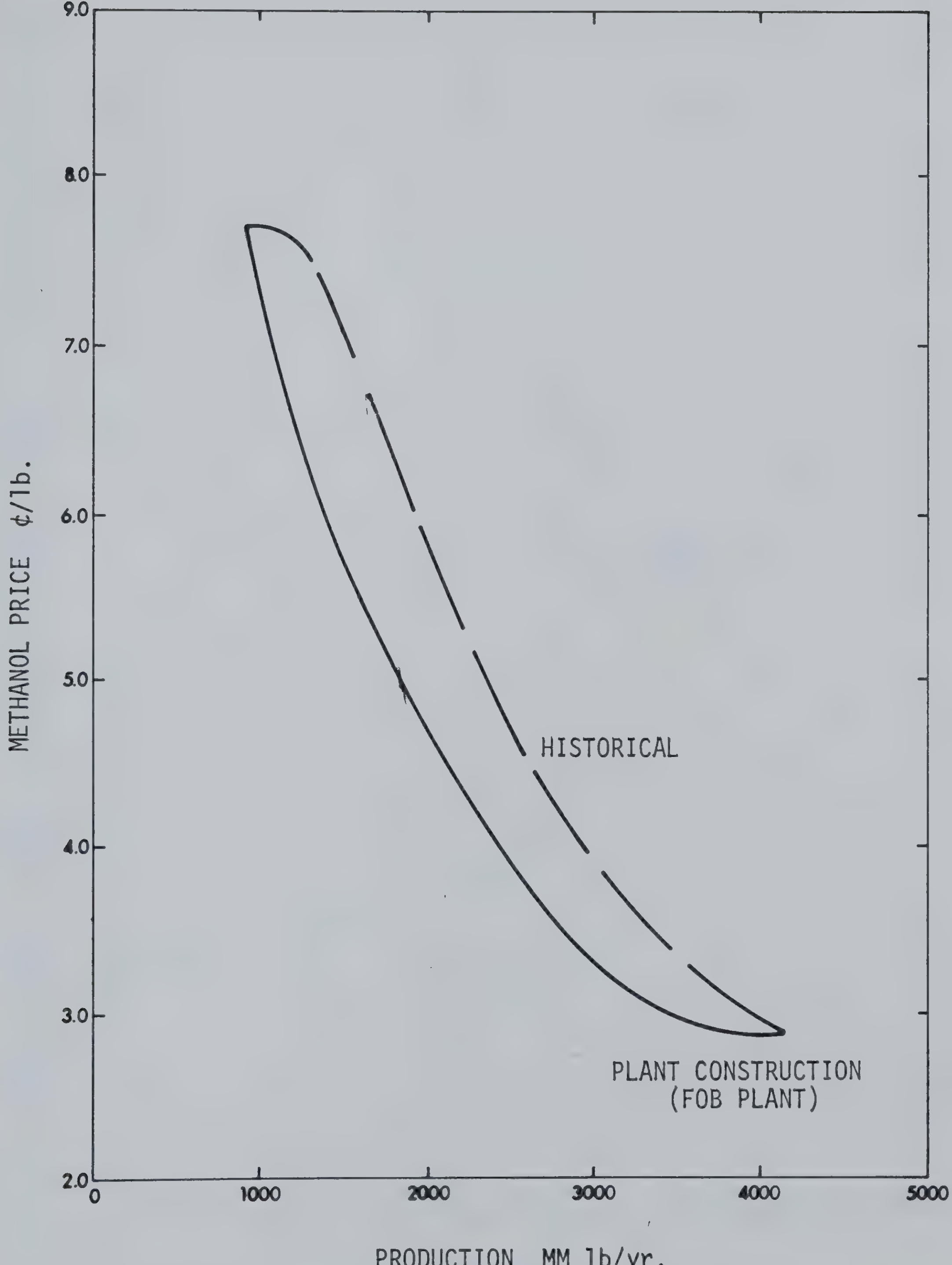

Figure 46. Comparison of Historical Methanol Price-Production Data and Supply Model Results Using Historical Production.

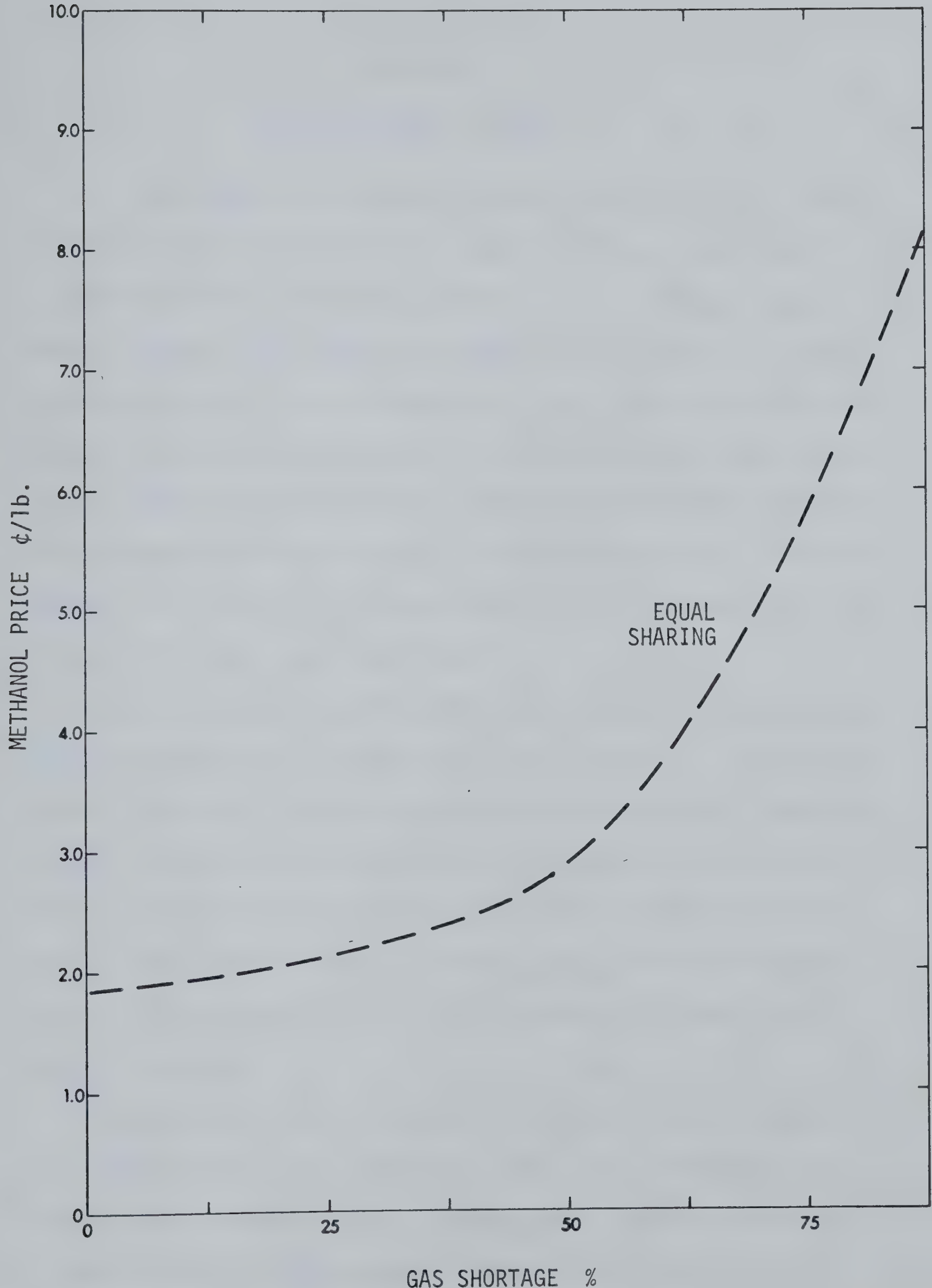

Figure 47. Effect of Gas Shortage on Methanol Prices

CHAPTER X

METHANOL-AMMONIA COMPARISON

In a gas shortage situation, certain industries are in a more advantageous position than others because their gas requirements form a smaller portion of operating expenses. As an example, consider the ammonia producer and a plant that manufactures paper cups. When a gas shortage occurs, which industry would pay more for natural gas? Because natural gas forms a much smaller percentage of paper cup production costs compared to ammonia, the paper cup producer could afford a higher natural gas price. The difference in the relative importance of the cost of feedstock implies that some industries can pay more for natural gas than others.

It is obvious that as the natural gas is further processed, the natural gas component of production costs decreases. This phenomenon was illustrated in the market study model decription. Hence secondary industries can afford higher gas prices than first-generation plants. But which first generation industry dictates natural gas price? This chapter attempts to answer that question by comparing the two largest primary chemical gas consumers, the ammonia and methanol industries.

The effect of natural price on methanol and ammonia prices is illustrated in Figure 48. As shown, a gas price of 50¢/Mcf was chosen as the reference point. A doubling of natural gas price to \$1.00/Mcf would increase ammonia price about 36% versus 40% for methanol. These prices were calculated based on the production

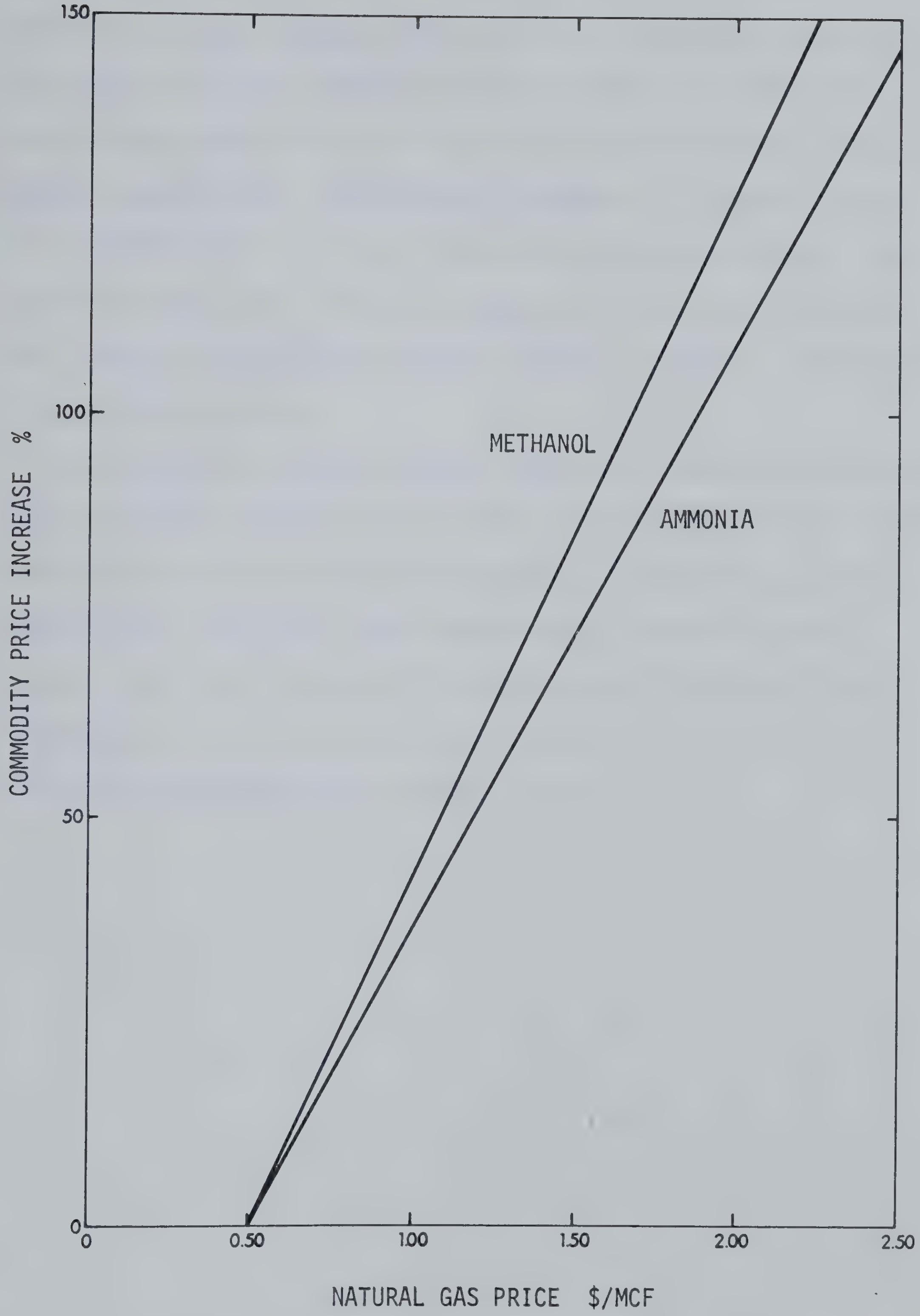

Figure 48. Effect of Natural Gas Price Increase on Methanol and Ammonia Prices

costs of the largest plants in existence: a billion lb/yr ammonia plant and 15 billion lb/yr methanol plant (14). Gas costs form a greater percentage of methanol production costs than ammonia. Hence, it is expected that ammonia producers can afford higher gas prices than methanol producers for a specific gas shortage. Of course, that gas price is dictated by the demand curves for ammonia and methanol. At some natural gas price, production costs exceed the market value for that chemical, and producers would be forced to stockpile production to increase market prices.

As gas price increases, however, alternative feedstocks, such as gas oil, naptha, synthetic gas from coal, and hydrogen all become more competitive with natural gas. Consequently, at some price, chemical producers will substitute these feedstocks for the traditionally cheaper natural gas. Appendix 1 contains a short analysis of the influence of one such alternative fuel, synthesis gas from coal, on natural gas consumption and commodity prices.

CHAPTER XI

CONCLUSIONS

1. The market penetration studies showed that the ammonia market would be much greater for an Alberta plant than the ethylene and methanol markets due to the existing tariff structure.
2. Removing the tariff barrier to Alberta exports and giving Alberta producers a $1.00/Mcf natural gas price advantage over U.S. producers allows Alberta chemicals to be marketed almost anywhere in the U.S.
3. Alberta-produced chemicals are not competitive with Middle East goods except in Western Canada and a small fraction of the Midwest U.S. due to the high cost of rail shipment compared to ocean transport and the lower-priced natural gas available in the Middle East.
4. The demand and price of fertilizer is regulated by farmer's cash income from grain sales. Because the price of fertilizer determines the gas prices fertilizer producers can afford, farmer's income influences the price of natural gas.
5. Ammonia producers can pay more for natural gas than methanol producers for specific natural gas shortage levels.

CHAPTER XII

RECOMMENDATIONS

1. The natural gas supply analysis should be extended to other industries, such as the electric power industry, secondary chemical industries, and possibly the steel industry. Which industries would establish the price of industrial natural gas could then be determined.
2. The question of alternative feedstocks to natural gas should also be examined. Coal is a possible substitute for natural gas in the production of methanol and ammonia, and naptha could be used in ethylene manufacture. The prices of these alternatives sets the upper bound on natural gas prices.
3. The effect of rising natural gas price on natural gas exploration and development should also be studied. For example, if gas prices escalate to $2.50/Mcf, reserves which were not economic to develop at low gas prices may become feasible.
4. Demand elasticities could also be estimated for other industries besides ammonia, although, as pointed out in the analysis, determining demand for other chemicals is extremely difficult.

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APPENDIX 1

COAL SUBSTITUTABILITY WITH NATURAL GAS

ALTERNATIVE FEEDSTOCKS

The purpose of this appendix is to demonstrate that natural gas price has an upper bound. That limiting price is the cost of substitutes, such as synthetic gas from coal, gas oil, naptha, and hydrogen.

When the price of natural gas exceeds the price of these substitutes, producers may convert their plants to use the alternative feedstocks, hence natural gas demand will rapidly decline. The price of natural gas at which coal becomes competitive will be determined in this appendix. Specifically, the costs of producing ammonia from natural gas and coal will be examined.

Table 40 shows the costs of producing ammonia from natural gas and coal. The coal production costs are based on the Texaco partial oxidation process (51). As illustrated, ammonia can be produced from $5/Ton coal at approximately the same cost as from 90¢/Mcf natural gas. Similarly, $5/Ton coal would be equivalent to natural gas costing $1.50/Mcf. The price of coal thus establishes the upper bound on natural gas prices. Through a similar analysis, the prices at which other alternatives become competitive with natural gas can be estimated. However, coal would appear to be the most viable substitute since coal reserves can supply the world for thousands of years at current consumption rates (51). Other hydrocarbon feedstocks have a very short lifespan.

Table 35

Ammonia Production Costs Using Coal and Natural Gas

(1000 T/Day Plant)

GAS PRICE \$/MCF	AMMONIA PRICE ¢/LB	COAL PRICE \$/TON	AMMONIA PRICE ¢/lb
0.50	2.6	5.0	3.26
1.00	3.5	10.0	3.76
1.50	4.4	15.0	4.26
2.00	5.2	20.0	4.76

SOURCE: Strelzoff (51)

APPENDIX 2

PLANT CONSTRUCTION MODEL VARIABLES

PLANT CONSTRUCTION MODEL VARIABLES

The plant construction model estimates when new chemical plants should be built. The decision to build is based on the criteria that new plants have lower production costs than existing plants. These production costs were identified in the market analysis, and are specific for a particular product being manufactured. Following are the parameters used in the computer program (listed in Appendix 3) to determine production costs:

CAP	is the capital cost of the plant.
VAR	is the raw material and utility costs.
LABOR	equals labor charges.
MAINT	represents maintenance costs.
OVERH,TAXES	equal overhead and taxes, respectively.
FXCST	equals the sum of overhead, maintenance, taxes and labor.
OPCST	is the total operating expenses.
DEP	is equivalent to depreciation.
SALES	is the total value of the chemical produced.
WORK	equals working capital.
FOB	is the plant gate price of the chemical.
COMP	is the new chemical price.
SIZE	equals plant size.
RATE	is the annual growth rate in chemical consumption.
OPROD	is the production before a new plant is built.
NPROD	is the production after a plant has been constructed.

APPENDIX 3

COMPUTER LISTING FOR SUPPLY ANALYSIS

PLANT CONSTRUCTION

```
C     THIS PROGRAM APPLIES THE PLANT CONSTRUCTION ANALYSIS
C     TO THE AMMONIA INDUSTRY.

      REAL MAIN,MAINT,NPROD,LABOR
      DIMENSION PRICE(20)

C     READ IN HISTORICAL NATURAL GAS PRICES.

      READ(5,70) (PRICE(I),I=1,20)
   70 FORMAT(10F5.2)

C     READ IN INITIAL CHEMICAL PRICE,ANNUAL GROWTH RATE.

      READ(5,80) COMP,RATE
   80 FORMAT(2F6.3)

C     READ IN FUEL COMPONENT,UTILITY,ADMINISTRATION,
C     AND MAINTENANCE COSTS,AND INITIAL PRODUCTION.

      READ(5,10) FUEL,UTIL,ADMIN,MAIN,PROD
   10 FORMAT(5F10.4)
      WRITE(6,20) PROD,FUEL,UTIL,ADMIN,MAIN
   20 FORMAT(' PRODUCTION     ',F10.4,'MM LB./YR.',//,' FUEL
     *REQUIRED  ',F10.5,//,' FUEL PRICE    ',F10.4,//,
     *' UTILITIES  ',F13.4,//,' SALES     ',F14.4,//
     *,'MAINTENANCE',F13.4)
      WRITE(6,90) COMP,RATE
   90 FORMAT(' COMP PRICE',F6.3,' CENTS/LB.',/,' RATE OF
     *INCREASE',F5.2,' PERCENT')
      RATE=RATE/100.
      N=1
      XFUEL=FUEL
      OPROD=PROD
    8 CONTINUE
      N=N+1
      COMP=((1.-ADMIN)*COMP+XFUEL*(PRICE(N)/PRICE(N-1)-1.))
     */(1.-ADMIN)

C     CALCULATE NEW PRODUCTION.

      NPROD=PROD*(1.+RATE)**(N-1)

C     CALCULATE NEW PLANT SIZE.

      SIZE=NPROD-OPROD

C     CALCULATE PRODUCTION COSTS FOR NEW PLANT.

      CAP=(SIZE/1050.)**.573*40.3E03
```

PLANT CONSTRUCTION...(CONT'D)

```
      VAR=(FUEL*PRICE(N)/PRICE(1)+UTIL)*SIZE*10.
      LABOR=259.*(SIZE/700.0)**0.2
      MAINT=MAIN*CAP
      OVERH=1.20*LABOR
      TAXES=0.015*CAP
      FXCST=OVERH+MAINT+TAXES+LABOR
      OPCST=VAR+FXCST
      DEP=0.10*CAP
      SALES=(1.02*OPCST+DEP+.2*CAP)/(0.98-ADMIN)
      WORK=.1*SALES+.1*OPCST
      FOB=SALES/SIZE/10.
      WRITE(6,30) CAP,WORK,SALES,FOB
   30 FORMAT(' CAPITAL COST $M',F13.4,/,' WORKING CAP  $M',
     *F13.4,/,' SALES      $M',F13.2,/,' FOB PRICE   ',F15.3,
     *' CENTS/LB.')
      IF(FOB-COMP)5,5,6
    5  COMP=FOB
      WRITE(6,91) FOB,SIZE,NPROD
   91  FORMAT(' NEW COMP PRICE',F13.3,/,' PLANT SIZE',F16.2,
     *'MM LB./YR.',/,' PRODUCTION',F16.2,//)
      OPROD=NPROD
      GO TO 7
    6 WRITE(6,100) NPROD,COMP
  100 FORMAT(' NO NEW PLANTS',/,' PRODUCTION',F16.2,' MM LB.
     */YR.',/,' NEW COMP PRICE',F13.3,' CENTS/LB.',//)
    7 CONTINUE

C     COMPARE NEW CHEMICAL PRICE TO CURRENT PRICE.

      XFUEL=XFUEL*PRICE(N)/PRICE(N-1)
      IF(N-21) 11,2,2
   11 CONTINUE
      GO TO 8
    2 CONTINUE
      CALL EXIT
      END
```

APPENDIX 4

PRODUCTION COST ESTIMATIONS FOR VARIOUS HYDROCARBONS

COST ESTIMATES FOR METHANOL PRODUCTION

This appendix contains a sample calculation of how production costs for methanol were estimated. The numbers quoted below were calculated using data from Hedley (13), although this was not the only source of methanol cost data.

DATA FOR A 800 MM LB/YR. PLANT (1970):

Capital Cost =$14.5 MM

Maintenance = 3.5% of Capital Cost

Taxes = 1.0% of Capital

Depreciation = 10% of Capital

Sales = 2% of Total Sales

Profit = 20% of Total Capital

Labour = .03¢/lb. @ $4.00/hr.

Gas Requirement = .32¢/lb @ 20¢/Mcf

Electricity = .018¢/lb. @ 65¢/Kwh

Catalyst = .05¢/lb.

Boiler Feed = .013¢/lb @95¢/1000 Gal.

Overhead = 120% Labour

The above data was then used to determine the operating costs for a 400 MM lb/yr. methanol plant. Captial costs were estimated using a 0.6 cost capacity factor and assuming a 10% inflationary increase annually:

Capital Cost (1977) = $\left(\frac{400}{800}\right)^{.6} (14.5)(1.1)^{7}$ = \$18.6 MM

Maintenance would then be 3.5% of capital cost, or \$0.68 MM. In cents per pound, maintenance would be:

$$\frac{\$0.68 \text{ MM}}{400 \text{ MM lb/yr. capacity}} = 0.17¢/\text{lb}$$

In a similar manner the remaining fixed costs (taxes, depreciation) were derived.

Utility, labour and raw material costs were then converted to more realistic values. As an example, labour salaries were assumed to increase to \$6.50/hr:

$$\text{Labour Cost} = \frac{6.50}{4.00}(.03) = .05¢/\text{lb}$$

The raw material and utility costs used in the market analysis are listed in Table 1 in Chapter II.

Working captial was assumed equal to 10% of sales plus 10% of manufacturing costs. For a 400 Mm lb/yr. plant, if the f.o.b. price was 2.5¢/lb. and operating expenses were 0.9¢/lb, working capital would be:

$$(.1(0.9) + .1(2.5))\ 400 \times 10^6 = \$1.35 \text{ MM}$$

Profit would then be 20% of working capital plus capital cost:

$$\frac{0.2(1.35 + 18.6)\$\text{MM}}{400 \text{ MM lbs.}} = 1.00¢/\text{lb}$$

The sales component for the methanol would be 2% of the f.o.b. price or 0.5¢/lb.

The above procedure was used in determining production costs for the various other chemicals which are tabulated in the market penetration chapters.

APPENDIX 5

LEAST SQUARES ANALYSIS TO DETERMINE A FUNCTIONAL RELATIONSHIP BETWEEN FERTILIZER SALES AND CASH GRAIN INCOME

LEAST SQUARES ANALYSIS

In determining the relationship between fertilizer sales and cash grain income in Chapter IX, a line was drawn visually through the data points. This, of course, introduces an error into the analysis.

However, when a least squares analysis was used to approximate the best straight line through the data points, the equation for the line was almost identical to that obtained visually. The two equations relating cash grain income and fertilizer sales are shown below:

Visual: Fertilizer Sales = 0.164 (Cash Grain Income) - 28.7

Least Squares: Fertilizers Sales = 0.160 (Cash Grain Income) - 26.3

Standard Deviation = 4.38

The high standard deviation implies a wide scattering of points, however, the difference between a visually fitted line and the least squares line would be minimal.

APPENDIX 6

REGRESSION ANALYSIS OF THE FERTILIZER DEMAND DATA OF CHAPTER IX

REGRESSION ANALYSIS OF ALBERTA FERTILIZER DEMAND

This appendix outlines a regression analysis which was applied to the fertilizer demand data used in Chapter IX. The analysis is based on Alberta fertilizer consumption and farmer's cash grain income for the years 1967 to 1974 only, as shown in Table 36, since data prior to 1967 did not correlate well. The pre-1967 period can be considered as a learning period where farmers experimented with manufactured fertilizer; demand was dictated more by time than by the price of fertilizer and farmer's income. It should be remembered that the fertilizer demand curves of Chapter VIII were based upon data as far back as 1955 because it was assumed that farmers would purchase fertilizer based on past behaviour. Therefore, the regression analysis presented in this appendix will produce a different fertilizer price-demand relationship from that of Chapter VIII For both analyses, however, fertilizer demand is assumed to be dependent on farmer's cash grain income.

Fertilizer demand as a function of cash grain income can be written as the following expression:

$$F = A_0 + A_1 \cdot CG \qquad (1)$$

where F is the money spent on fertilizer in \$ MM in any year, and CG is the cash grain payments to the farmer including inventory changes for the same year, ie. the data was not lagged one year as in the demand analysis of Chapter VIII.

TABLE 36

HISTORICAL CASH GRAIN INCOME AND FERTILIZER SALES IN ALBERTA

YEAR	CASH GRAIN INCOME $MM	FERTILIZER SALES $MM
1974	862.9	71.2
1973	469.1	46.2
1972	389.4	35.2
1971	325.0	31.3
1970	259.9	27.7
1969	290.2	27.9
1968	371.2	41.3
1967	387.5	36.3

SOURCE: (39, 40, 41)

When a regression anslysis was applied to the data of Table 36 the results of the fit were as follows:

$A_o = 6.96 \pm 2.54$ at a 90% confidence level

$A_1 = .07647 \pm .0098$ at a 90% confidence level

The correlation coefficient was $r = .9876$ which is excellent.

Substituting the above parameters into equation (1) yields:

$$F = 6.96 + .07647\ CG \qquad (2)$$

The next problem was to relate cash grain income to grain price and production. Cash grain income equals total crop sales times average crop price. From historical data (39, 40,41), it was determined that the average Alberta grain production for the last five years was about 1700 lbs/acre and an average of 13.2 MM acres were seeded. The ratio of crop sales to production was estimated to be about 0.68 for the period 1967 to 1974. The fertilizer demand equation can therefore be written as:

$$F = 6.96 * 10^6 + .07646\ (.68\ (1.7 * 10^3 * 13.2 * 10^6)\ PG) \qquad (3)$$

where PG is the price of grain in \$/lb. F, the total fertilizer expenditures by the farmer, equals fertilizer price times demand. Substituting for F and simplifying equation(3)yields:

$$\underset{\text{(Tons)}}{\text{Fertilizer Demand}} = \frac{6.96 * 10^6 + 1.097 * 10^8 * \text{Price of Grain in \$/lb}}{\text{Price of Fertilizer in \$/Ton}} \qquad (4)$$

The equivalent price of \$1.00/bushel grain, based on the weighted average production of all grains over the last 15 years (39, 40, 41), is \$0.0205/lb. When fertilizer prices varying from \$50 to \$300/ton are substituted in equation (4), the dotted lines shown in Figure 49 are obtained

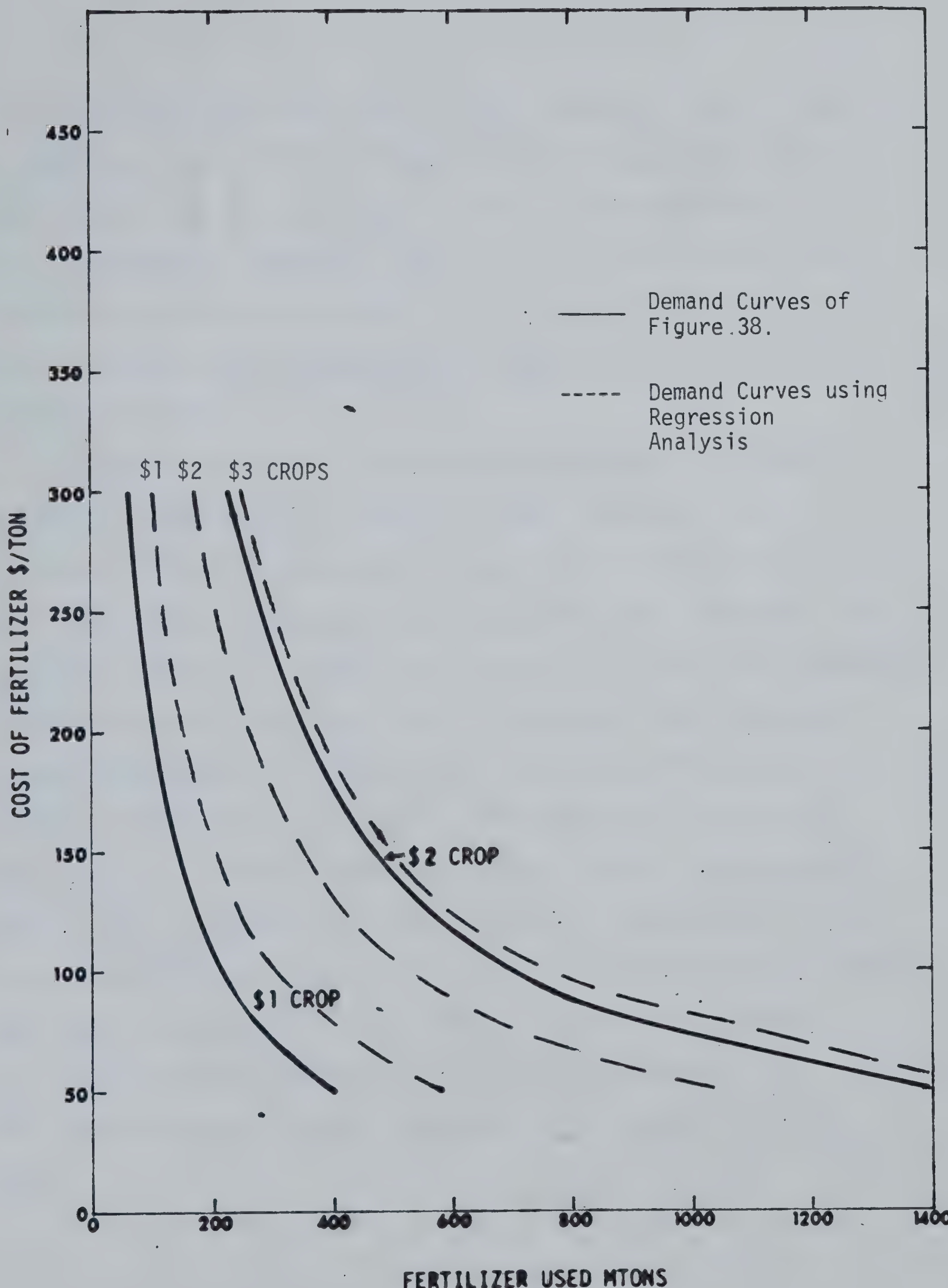

Figure 49. Effect of a Regression Analysis on Figure 41. Fertilizer Demand Curves

for \$1, \$2, and \$3 per bushel grain prices. The solid lines of Figure 49 are identical to the fertilizer demand curves of Figure 38 and represent the effect of crop price on Alberta fertilizer consumption based on historical behaviour from 1955 to 1974. For simplicity, the two sets of curves illustrated in Figure 49 will be called the regression fertilizer demand curves (dotted) and the historical fertilizer demand curves (solid lines).

As shown in Figure 49, the fertilizer consumption for \$1 grain determined by the regression analysis is almost identical to the historical fertilizer demand curve. However, the \$3 regression curve is equivalent to the \$2 historical fertilizer demand curve, therefore, using data prior to 1967 almost doubles the sensitivity of fertilizer consumption to fluctuations in average crop prices. Regardless of which approach is used in estimating the effect of crop price on fertilizer demand, it is obvious that fertilizer consumption drops dramatically when crop prices decline at constant fertilizer prices. Based on the regression curves, a drop in average crop price from \$3 to \$2 would result in a 30% decline in fertilizer consumption at a constant fertilizer price. Therefore, considering the pre-1967 as a learning period where farmers experimented with fertilizer would not alter the conclusion that fertilizer consumption is highly dependent on the average cash crop price.